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UV LED and Excimer Curing

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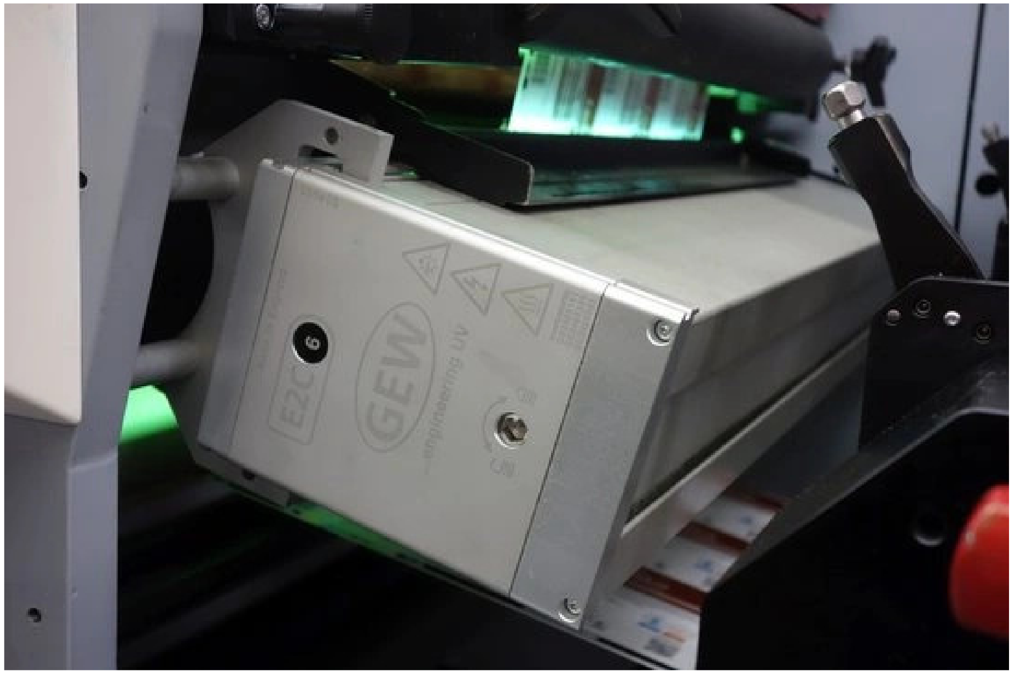
...engineering UV

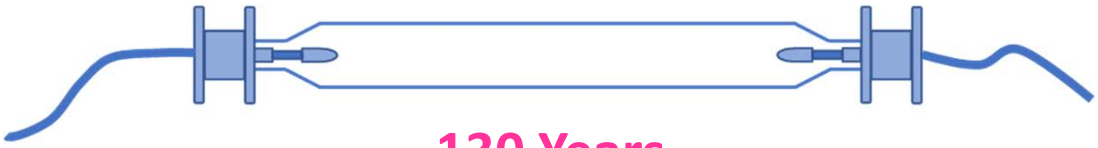
UV Curing



UV curing is a photochemical reaction that harnesses energy stored in wavelengths of ultraviolet light to set and adhere inks, coatings, adhesives and extrusions in manufacturing processes by reacting the molecular bonds of applied materials

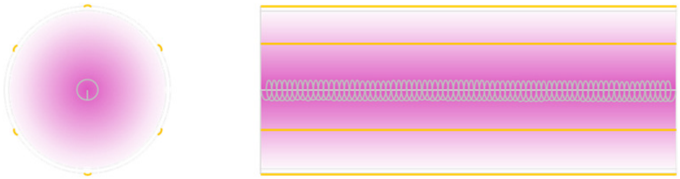
UV Curing Sources

Mercury Arc
(medium pressure gas discharge)



130 Years

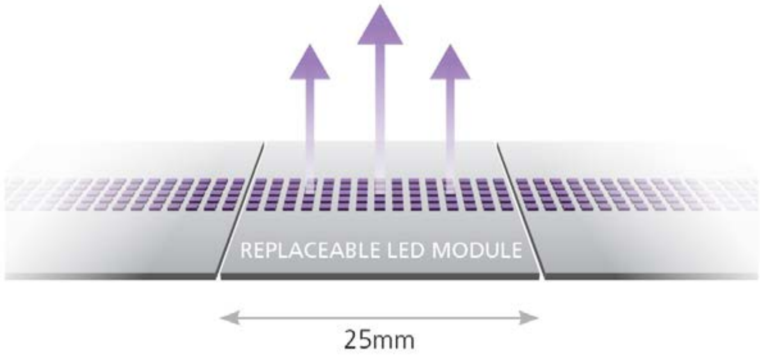
Excimer
(dielectric barrier discharge)



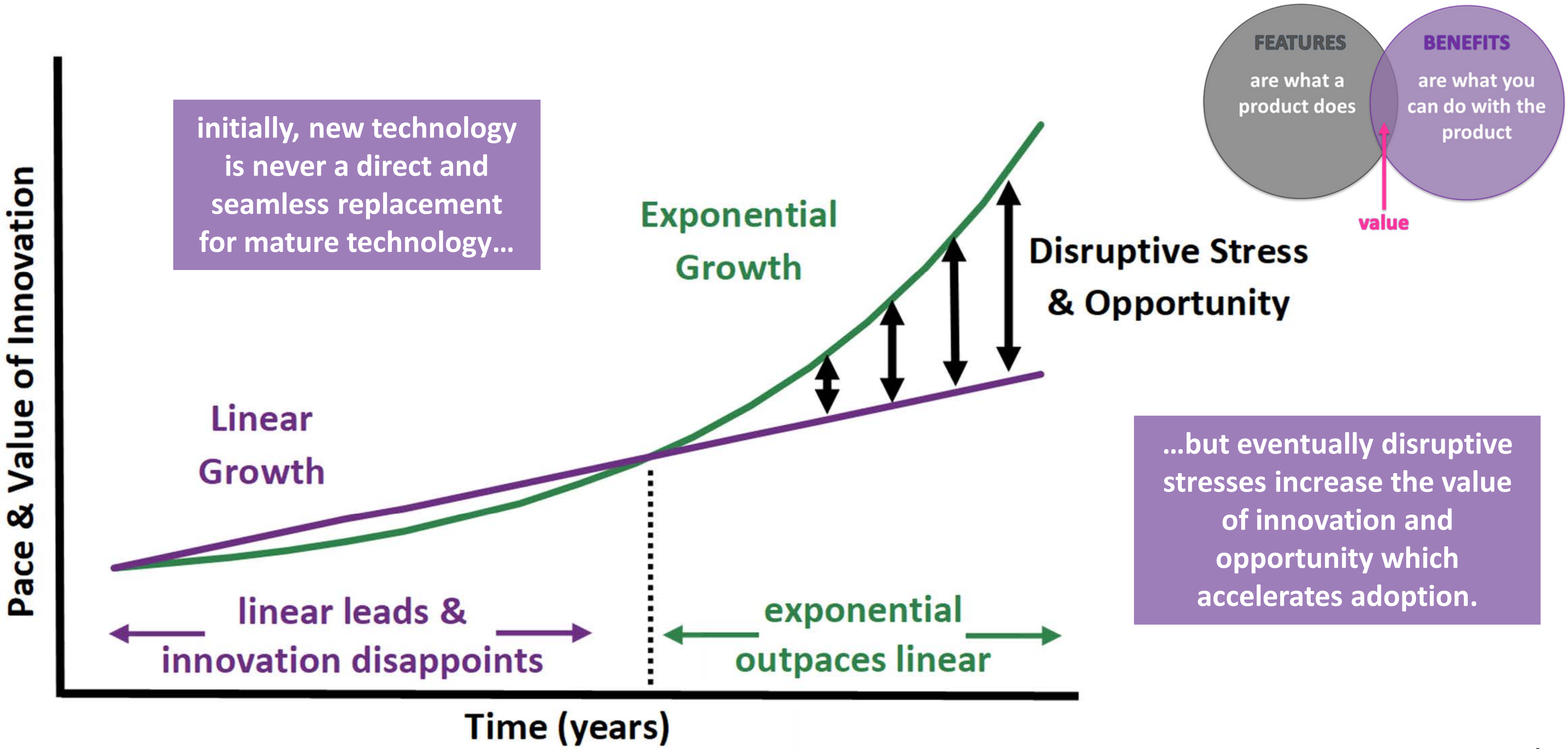
30 Years

Light Emitting Diode
(solid state semi-conductors)

20 Years



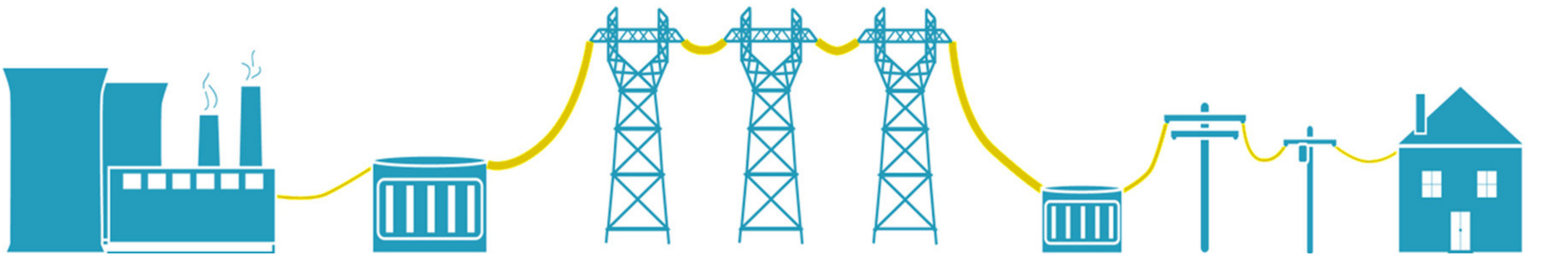
Adoption of New Technology



UV LED’s value proposition for wood coatings

- no infrared output means less thermal transfer and lower board surface temperatures
- more efficient at converting electricity to UV output
- instant on off
- no ozone generation
- longer life, less maintenance, no consumables
- slow LED degradation means better process control over time
- often reduces total number of lamps

LED’s growing value due to sustainability



REDUCE
REUSE
RECYCLE

all electric

reduces total installed system power

reduces peak demand at start-up

reduces energy consumption during operation

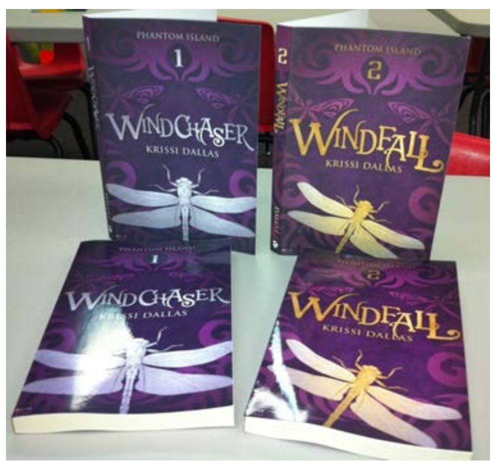
reduces GHG footprint – Scope 1, 2, and 3

Excimer's value proposition for wood coatings

anti-glare
anti-fingerprint
anti-reflective
improved stain resistance
easy to clean
communicates naturalness
communicates elegance, sophistication, luxuriousness
communicates environmental friendliness
provides product longevity
matte in combination with gloss creates appearance of depth and provides contrast
encourages buyers to handle and purchase product

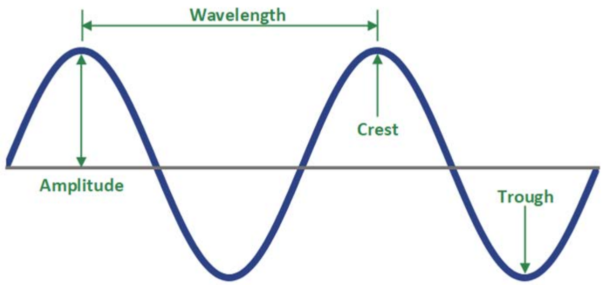
Excimer’s growing value due to matte surface trends

labels
flexible packaging
rigid packaging
commercial printing
furniture
cabinets
flooring
electronics
appliances
home décor



Characterizing UV output

- **wavelength (nm) is 395 nm**
  - *distance* between corresponding points on a wave
  - a nanometer (nm) is a billionth of a meter
  - a sheet of paper is 100,000 nm thick; UV is between 100 and 450 nm
- **irradiance (W/cm^2) or intensity**
  - radiant power arriving at a surface from all forward angles per unit area
  - *dose rate* ($J/cm^2/sec$) or rate of energy delivery
- **energy density (J/cm^2) or dose**
  - *total radiant energy over time* arriving at a surface per unit area
  - integration of irradiance over exposure time (area under the irradiance profile)
- **electrical power (W/cm or W/inch)**
  - *nominal specification*: wattage of power supply / length of lamp
  - doesn't capture efficiency, lamphead design, set-up, process conditions



Excimer is short VUV and LED is long UVA

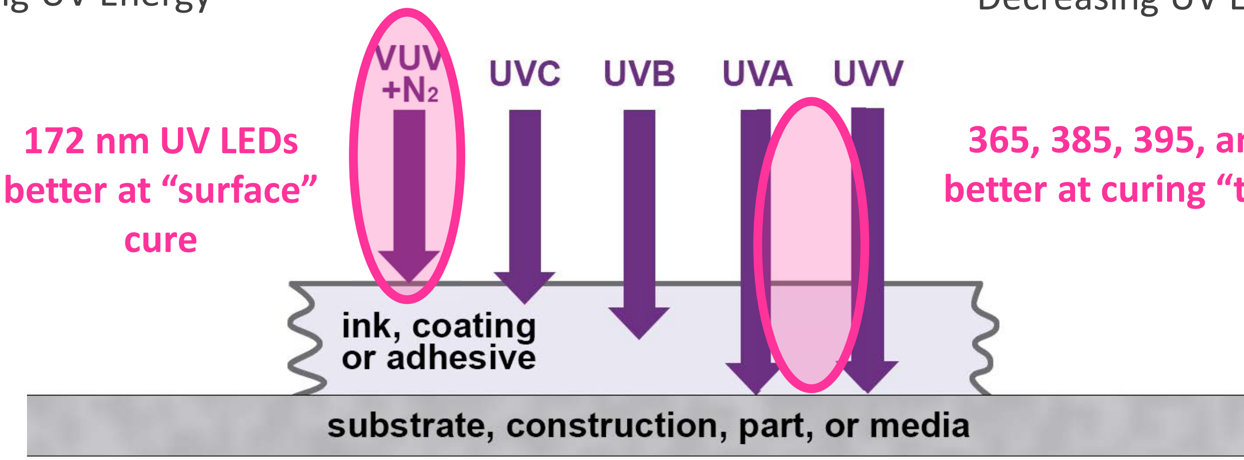
Decreasing Wavelength & Penetration
Increasing UV Energy

100 to 450 nm

Increasing Wavelength & Penetration
Decreasing UV Energy

a single sheet of paper is 100,000 nm (0.004") thick

172 nm UV LEDs better at "surface" cure



365, 385, 395, and 405 nm UV LEDs better at curing "through" and "deep"

Vacuum UV:	100 – 200 nm	UVB:	285 – 315 nm	UVV:	400 – 450 nm	Infrared:	700 nm to 1 mm
UVC:	200 – 285 nm	UVA:	315 – 400 nm	Visible:	400 – 700 nm		

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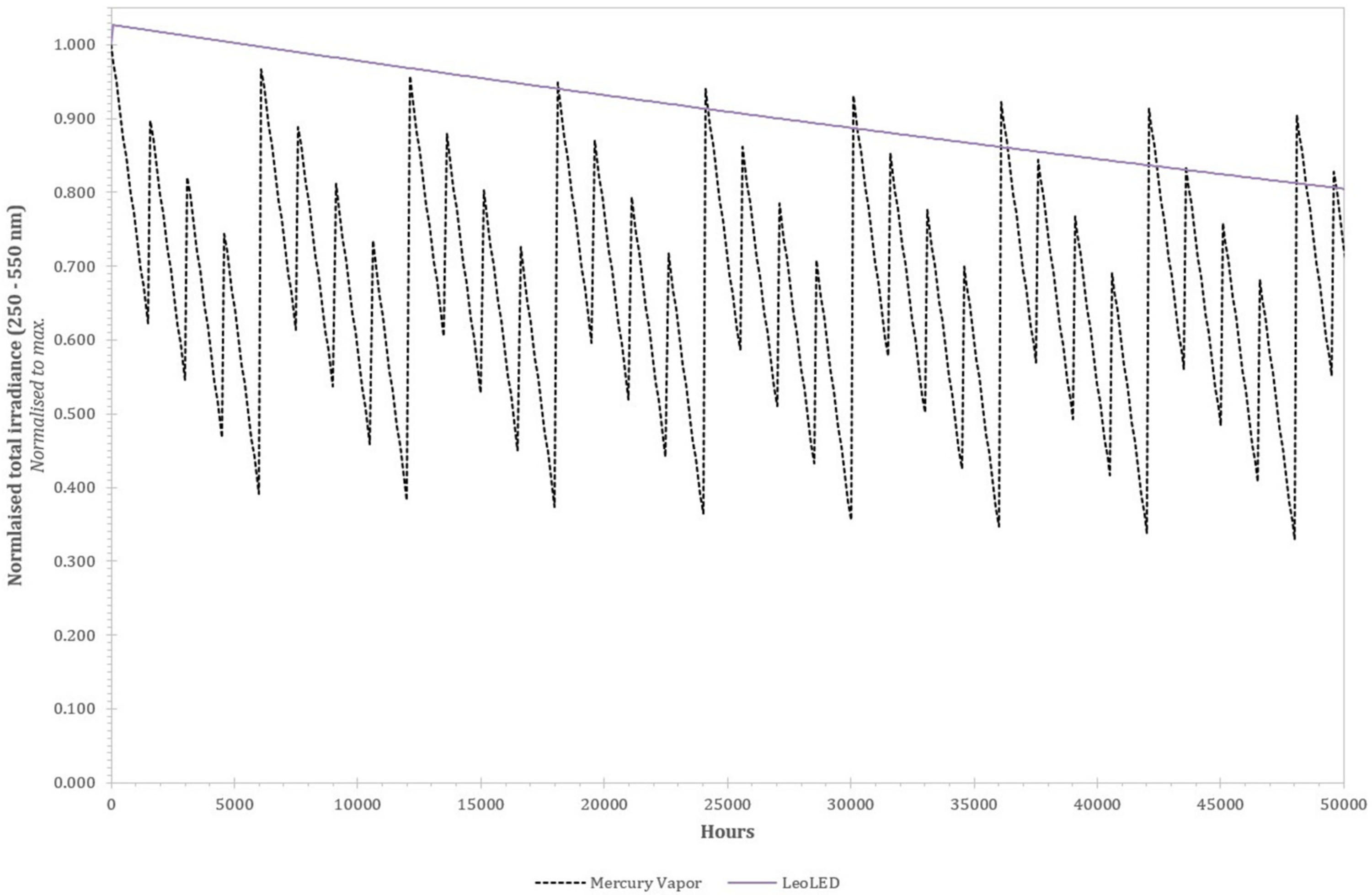
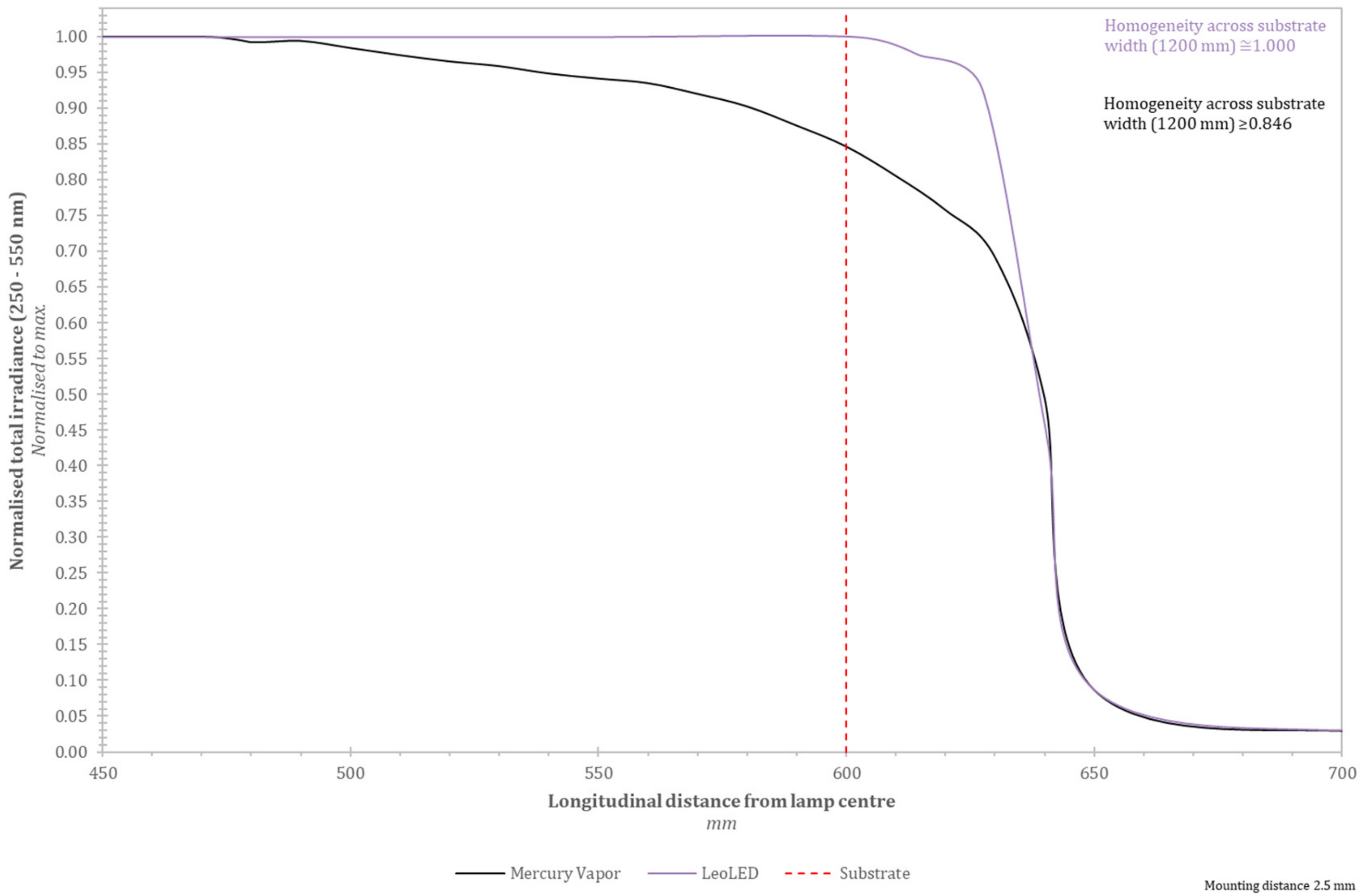
Mercury vapor vs. LED Lifetime



LED Lifetime

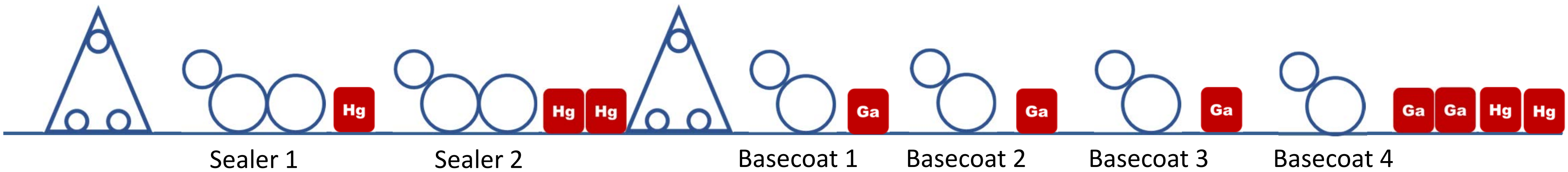
- LM-80-21
  - Measuring maintenance of light output characteristics of solid-state light sources
- L70
  - Time (hours) when the luminous flux output from the LED has dropped to 70% of initial value
- TM-21-21
  - Projecting long-term luminous, photon, and radiant flux maintenance of LED light sources

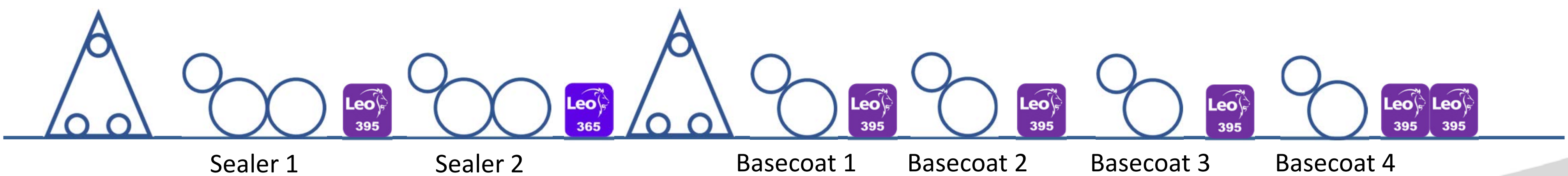
Homogeneity



Energy Comparison

- 10-lamp Mercury lamp line
- 7-lamp LED lamp line





Energy Comparison

Assumptions		
Mains Voltage (V)	400V	
Mains Frequency (Hz)	50Hz	
Duty cycle	70%	The proportion of the shift that the system is on full power
Days per year	294	Total days of operation in a 365 day year
Shifts per day	3	Average number of shifts in a day
Hours per shift	8	Average number of hours per shift
Energy cost	0.2 EUR	Average cost per kW hour

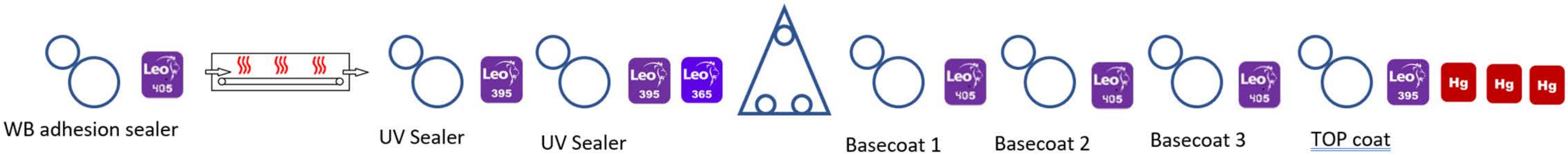
UV system specifications	existing	LeoLED	Notes
Length	130cm	130cm	Length of lamp / LED array
Power	120W/cm	57W/cm	Input power of lamphead
Number of UV lamps	10	7	Number of UV lampheads on the press

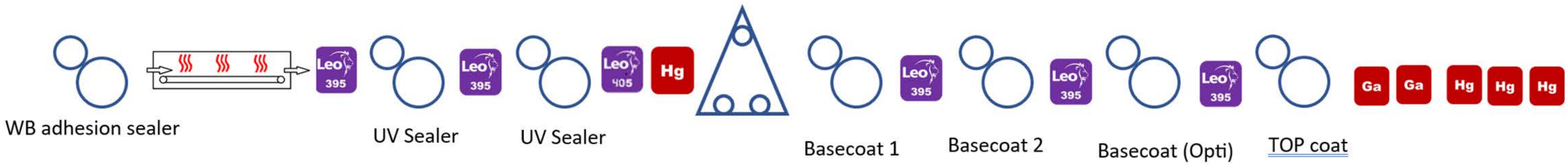
Comparison		Notes
Annual savings from LeoLED	**166,714 EUR**	Estimated annual savings of LeoLED system over arc system
Energy saved annually	**618,195kWh**	63.3% reduction in energy usage annually
Carbon footprint reduction	**210.19 Tonnes of CO_2**	Estimated carbon footprint reduction per annum

Flatbed conveyor integration

Line conversions – Internal Doors

Line conversions – Furniture and Parquet



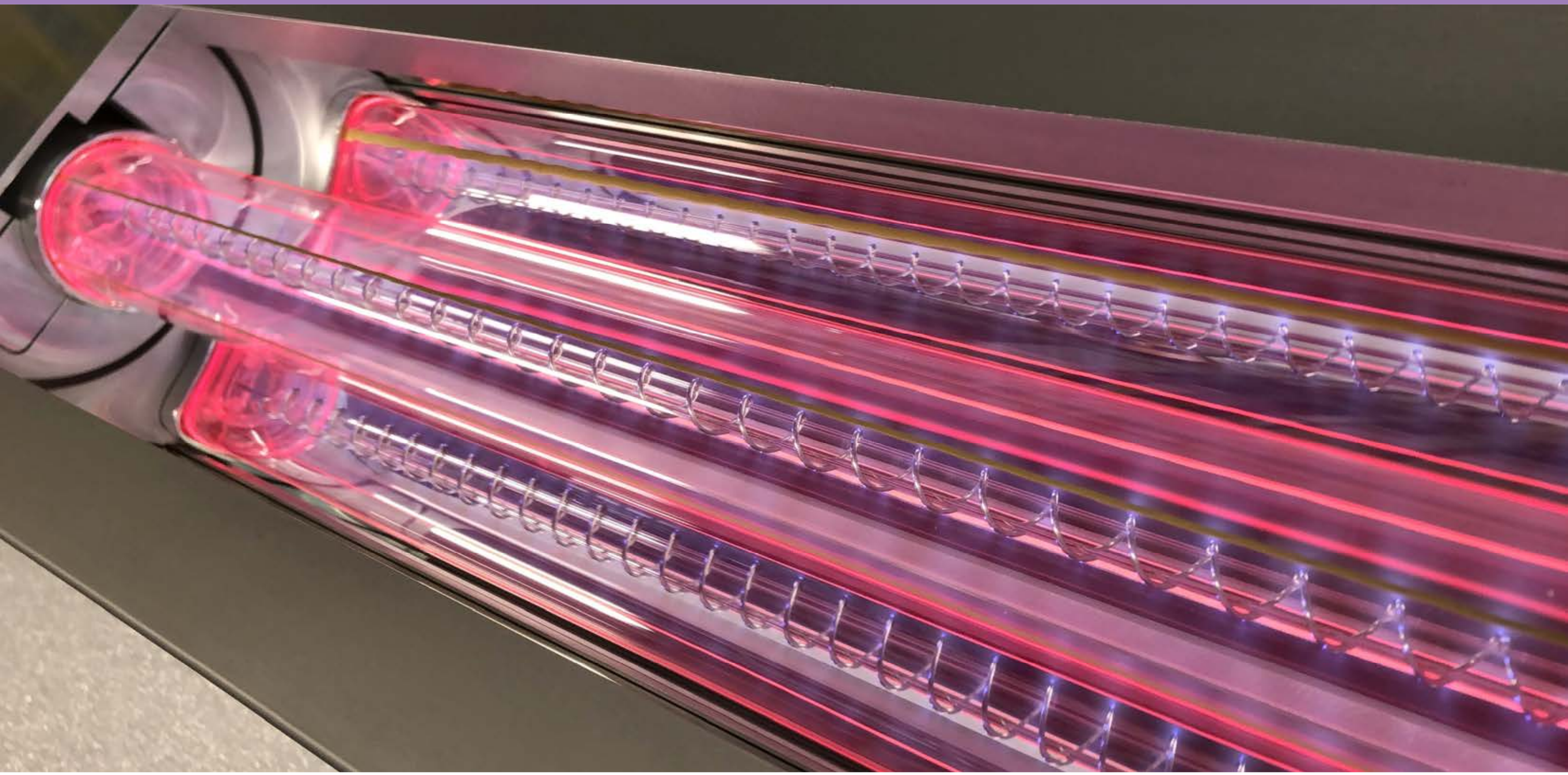


Line conversions – Plywood

GEW UV vision combi LED UV:

GEW UV vision 2 **–** FULL LED:

Science behind excimer lamps



Science behind excimer lamps

- An excimer lamp is a quasi-monochromatic source of UV radiation
  - **172 nm (mattifying)**
  - 222 nm (mutagenic)
  - 308 nm (melanocytic)

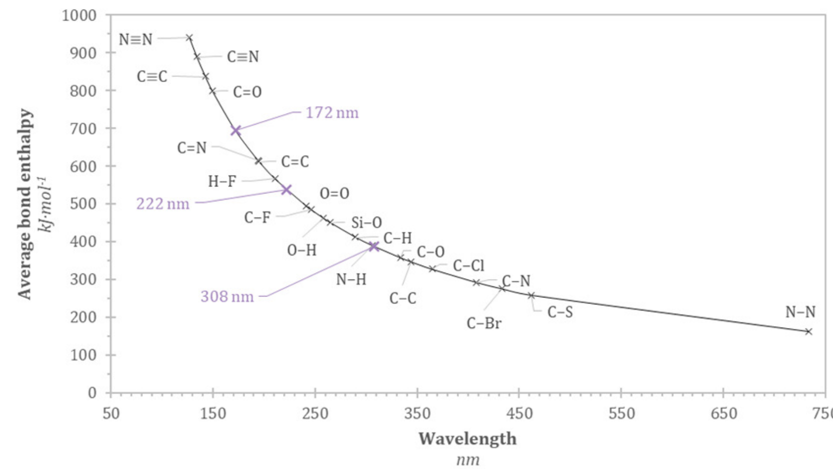
- UV radiation is emitted when the working excimer (**exci**ted di**mer**) or exciplex (**exci**ted com**plex**) molecule transits from an excited state to a ground state

$$Xe_2^* \rightarrow Xe_2 + h\nu \rightarrow Xe + Xe$$

172 nm example

What is excimer?

- High photonic energy
  - 172 nm → ≅7.21 eV
  - Typical chromophores (i.e. photoinitiators) not required



- High spectral energy density (FWHM 14 nm)
  - Negligible IR and VIS emission
    - Typical lamp temperature 100 – 150 °C

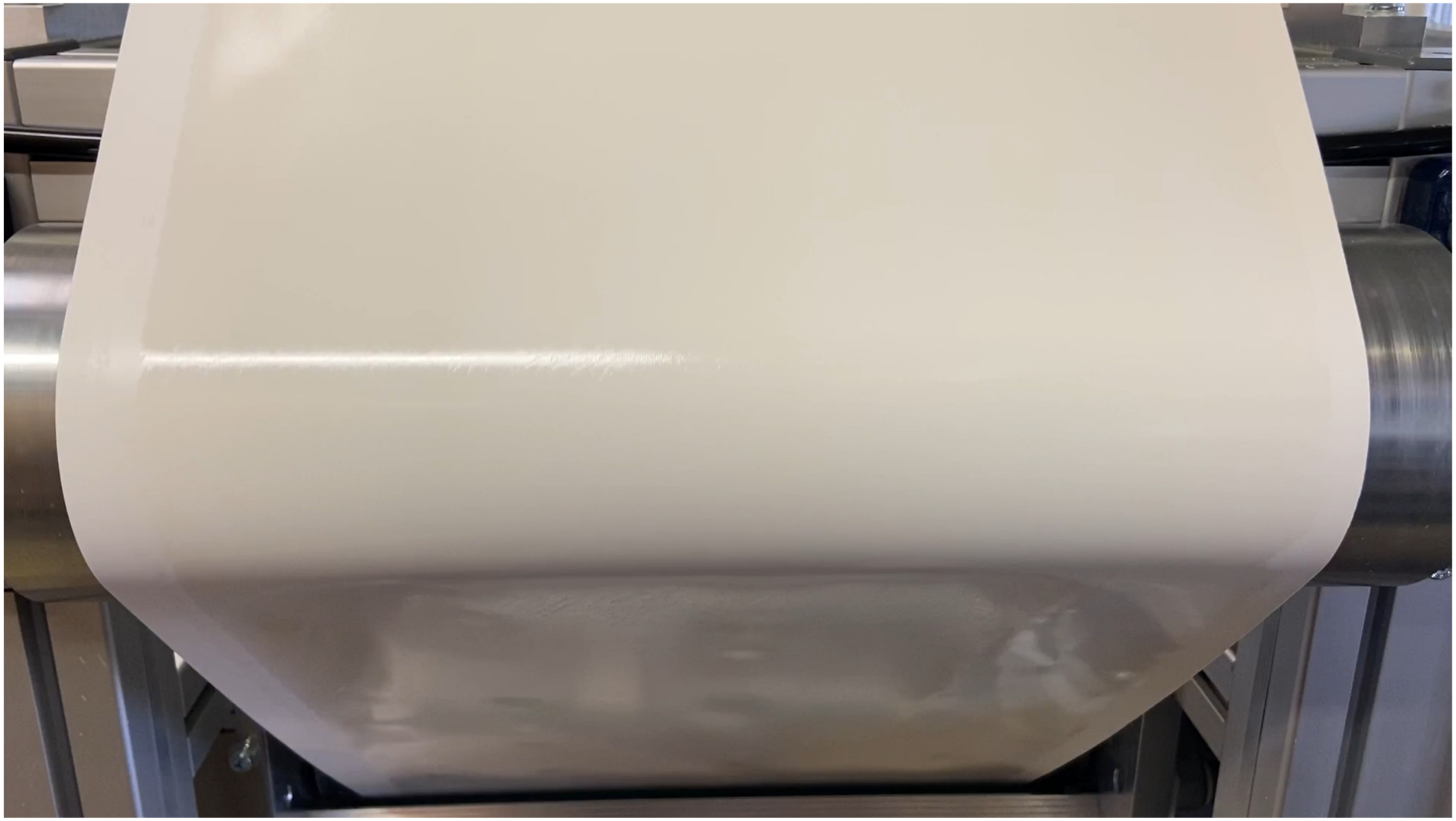
- Inert atmosphere necessary
  - Oxygen functionalisation
  - Oxygen inhibition

Science behind excimer lamps

- High-energy 172 nm radiation is limited in its penetration depth, causing the polymerised phase to contract on the underlying ‘soft’/uncured phase

- As mattifying agents are not necessary there is improved resistance to contamination, uniform chemical durability, increased hardness, preferable haptics, and preservation of translucency

Gloss vs Matte with the flip of a switch



Gloss Reading vs Human Perception

UV-LED pre-gelling: ---
ExciRay mattification: ---
NA2 final-curing: ✓

GU @ 60°: 53.9
GU @ 85°: n/a

UV-LED pre-gelling: ---
ExciRay mattification: ✓
NA2 final-curing: ✓

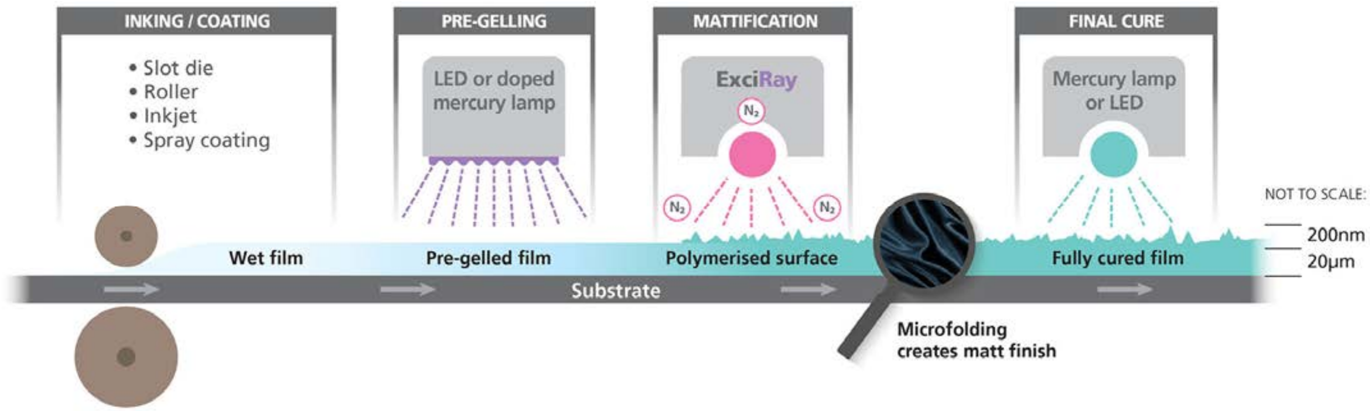
GU @ 60°: 2.5
GU @ 85°: 6.2

UV-LED pre-gelling: ✓
ExciRay mattification: ✓
NA2 final-curing: ✓

GU @ 60°: 2.2
GU @ 85°: 22.0

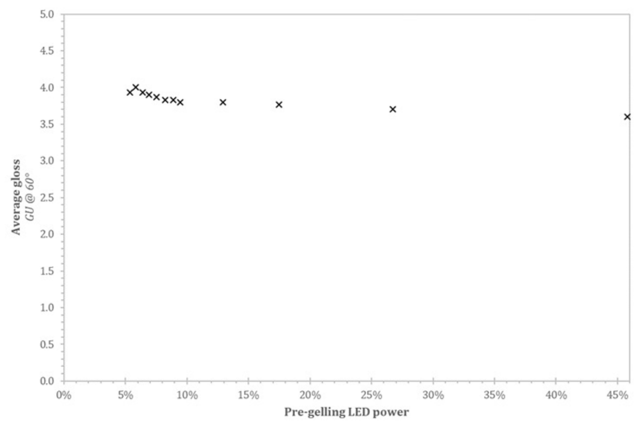
How to excimer?

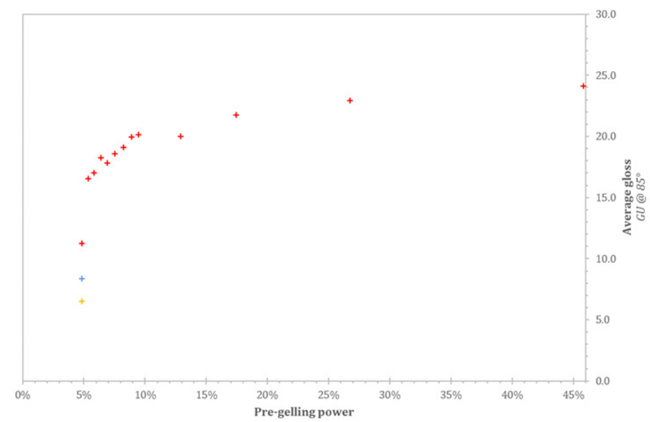
1. Pre-gelling
2. Mattification
3. Final-cure
4. Nitrogen inertisation



How to excimer? 1. Pre-gelling

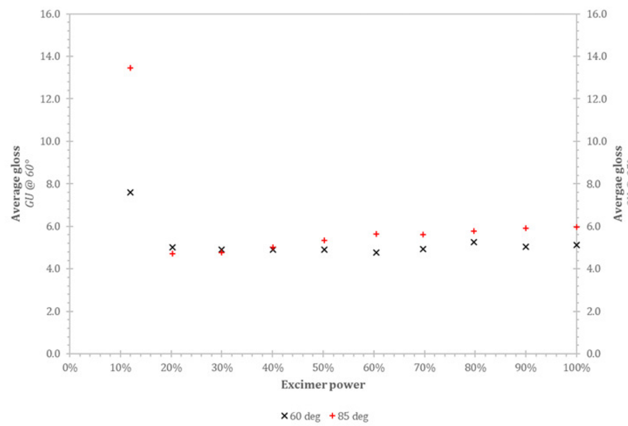
- The **GU @ 60°** change resulting from **pre-gelling power variation is negligible** but there is a **significant change** in the **GU @ 85°** with the appearance, and GU @ 85°, becoming more 'satin'

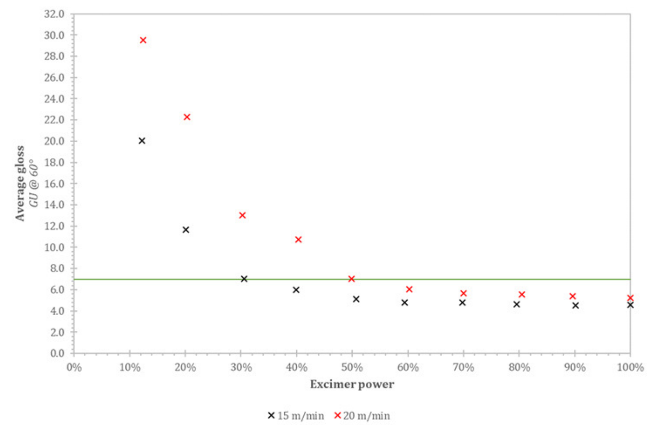




How to excimer? 2. Mattification

- The **GU @ 60°** change resulting from **excimer power variation is negligible**. **Lower excimer power is preferential** (increased mattifying) as the polymerised layer is thinnest and therefore contracts more easily





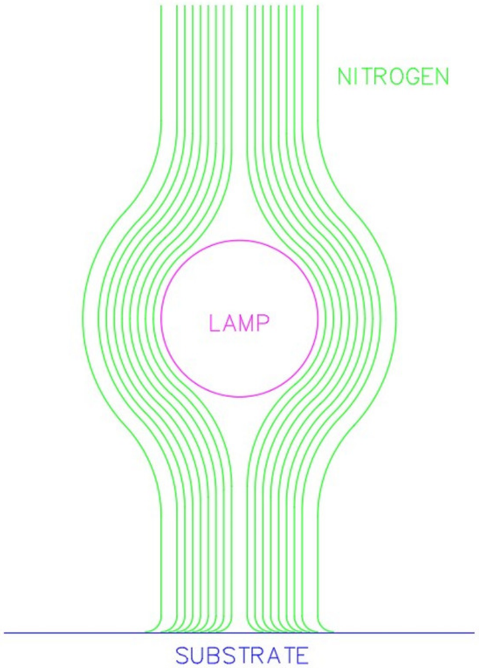
GEW ...engineering UV

How to excimer? 3. Final-cure

- UVA-LED or polychromatic conventional UV luminaires
- Depth curing
- Shares inert chamber of excimer irradiation zone
  - Consider substrate requirements

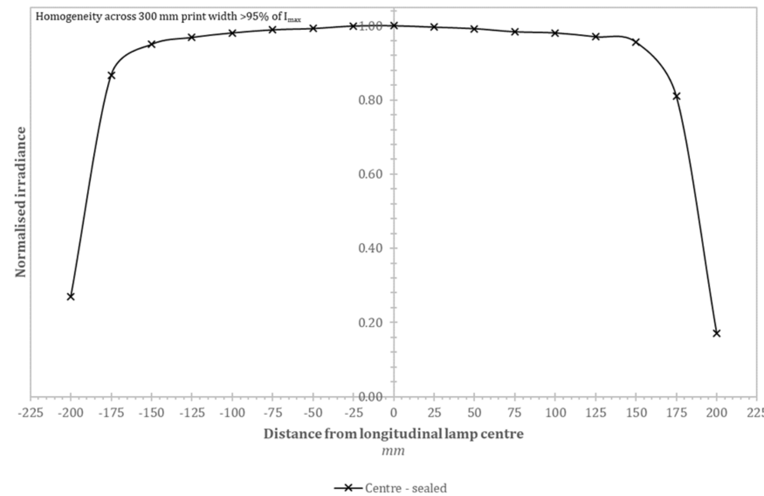
How to excimer? 4. Nitrogen inertisation

- Boundary layer removal of adsorped oxygen
- Flushing/flooding removal of ambient oxygen
  - Irradiation chamber
  - Localised excimer zone
- Lamp cooling for high-power applications



How to excimer? 4. Nitrogen inertisation

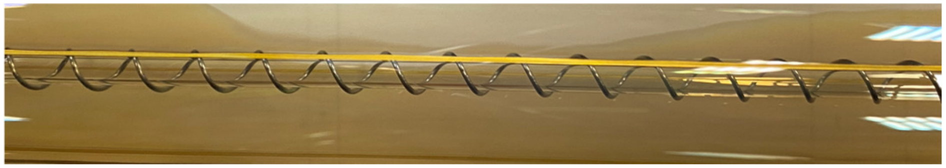
- Homogeneity
- Coandă effect
  - Beware of low-pressure vortices
- Low residual oxygen concentration
  - Typically, <500 ppm
  - Oxygen functionalisation promotion
    - Aids with lamp life during operation



...engineering UV

Process considerations?

- Beware of high vapour pressure components
  - Substrate
    - Plasticisers
    - Natural resins
    - Absolute moisture content (AMC)
  - Ink/coating
    - Monomer and oligomer functionality
    - Residual solvents from component suspensions
    - End-user processing agents (e.g. slip additives)



Why excimer?

- Various application methods
  - Roller
  - Curtain
  - Spray
  - Inkjet
  - Mayer bar
  - Gravure
- Faster line speeds
  - Additives can change the viscosity of the coating
- Increased wear-resistance
  - Reduction in polishing effect from post-processes

- Improved stain resistance performance
  - Iodine
  - Coffee, wine, etc.
- ‘Deep-matte’ possible
- Backwards compatibility
  - Additives can still be used
- Reduction in ‘fingerprinting’
- Enhanced reproducibility
- Homogeneous transparency

- ‘Soft-touch’
- Thermoformable
- Solvent-free
- Silica-free
  - Avoid stress whitening on flexible substrates
- Reduction in PI content
  - When compared to non-inerted systems

Closing Thoughts

UV LED and excimer technology is providing solutions, operationally and functionally, to current environmental and sustainability demands

WOOD COATINGS AND SUBSTRATES CONFERENCE 2024

Thank you!

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