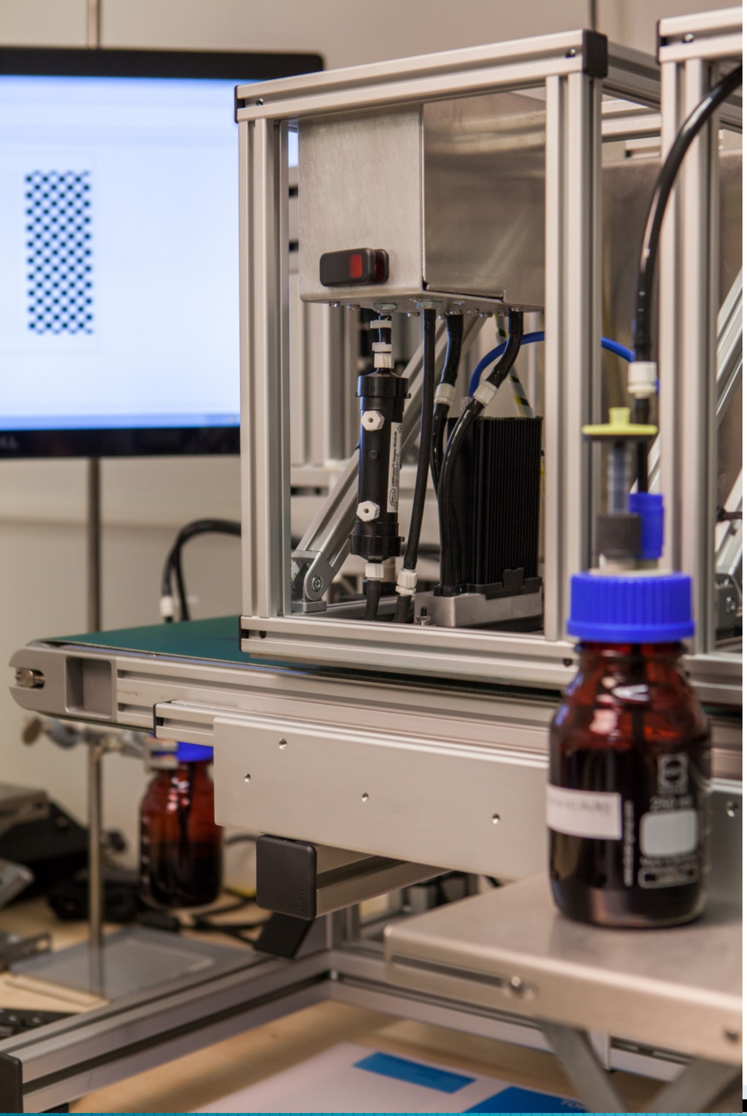
CHEMSTREAM
SUSTAINABLE CHEMISTRY



System Integration: an ink point of view

Frank De Voeght
30/09/2014
The IJ Conference – Dusseldorf

www.chemstream.be

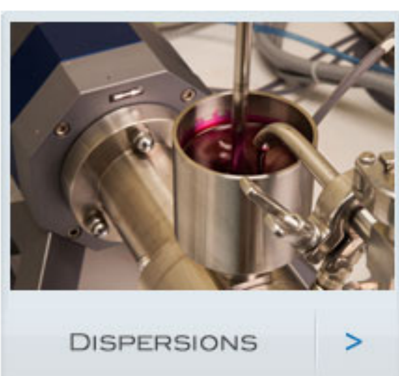
Company Profile
Chemical Research Company

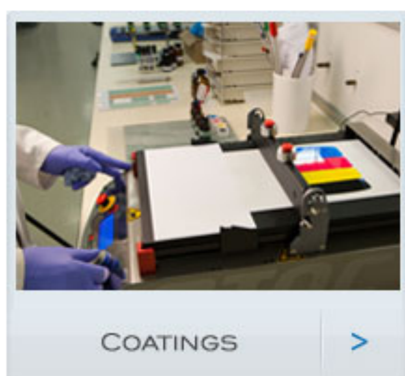
CHEMSTREAM

Since: April 2010
Staff: 5 PhD’s in chemistry and material science

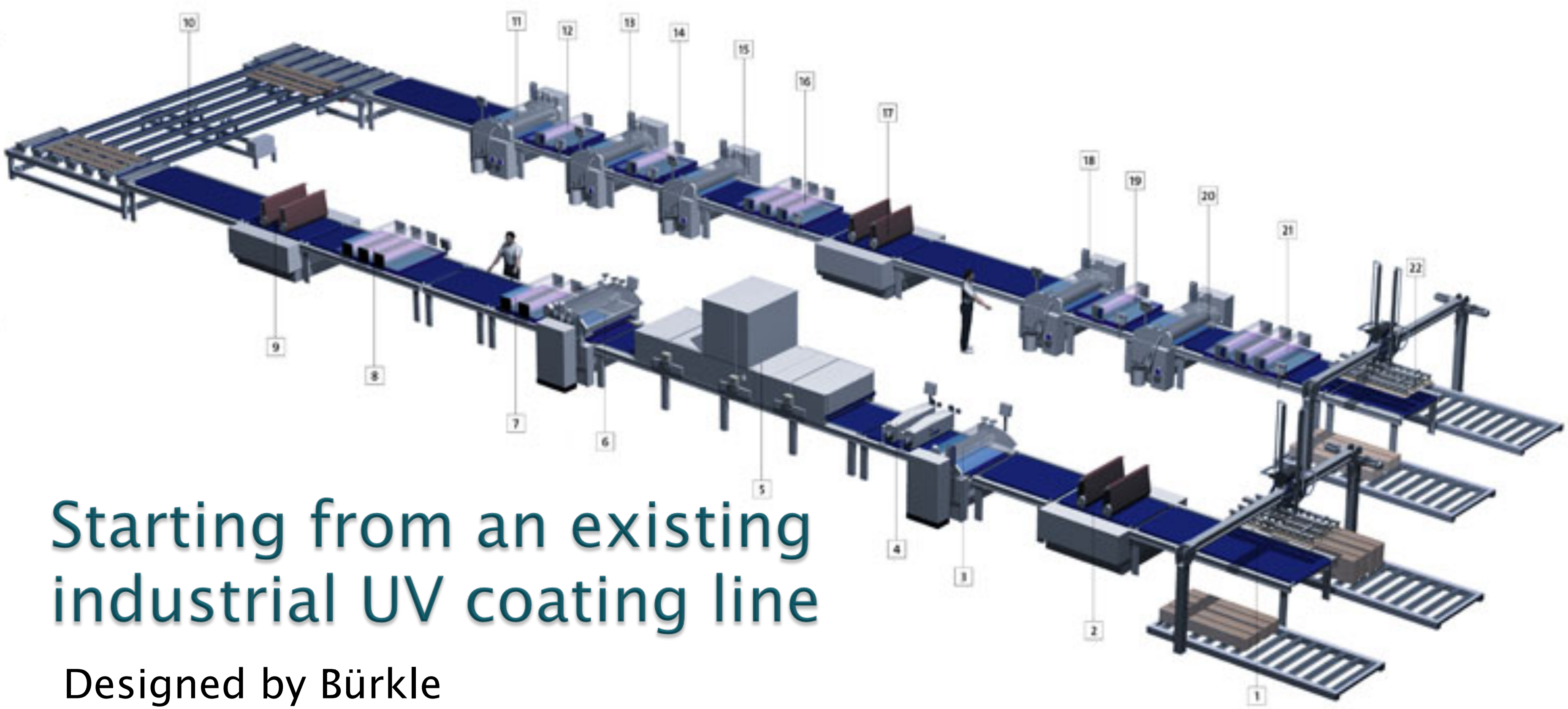
Core activities:

- Customized product development
- Innovative contract research
- Designing, formulating, prototyping
- Organic synthesis, Molecular modeling, Design of experiments (D.O.E.), Analytical techniques, …





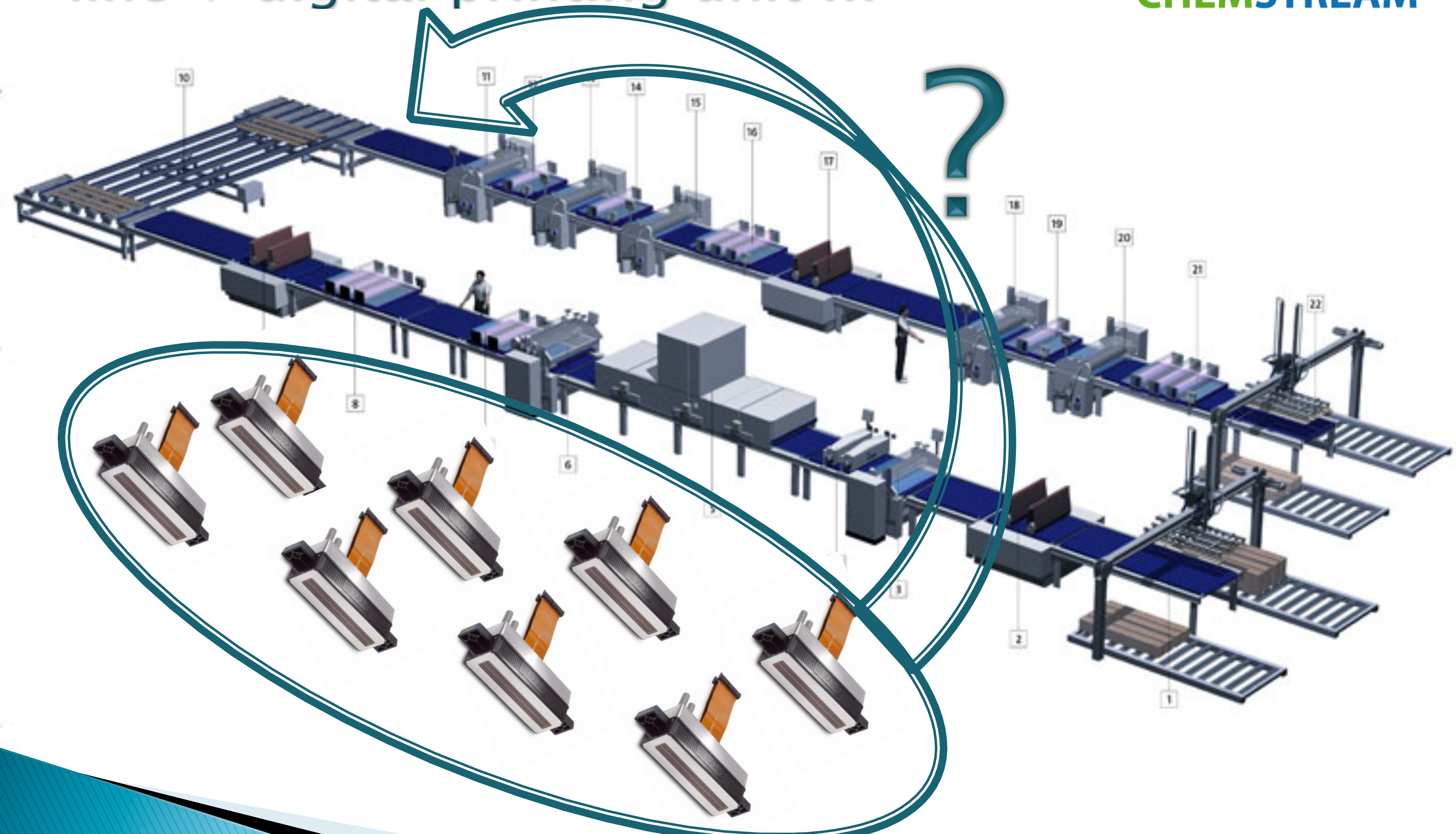
System integration…



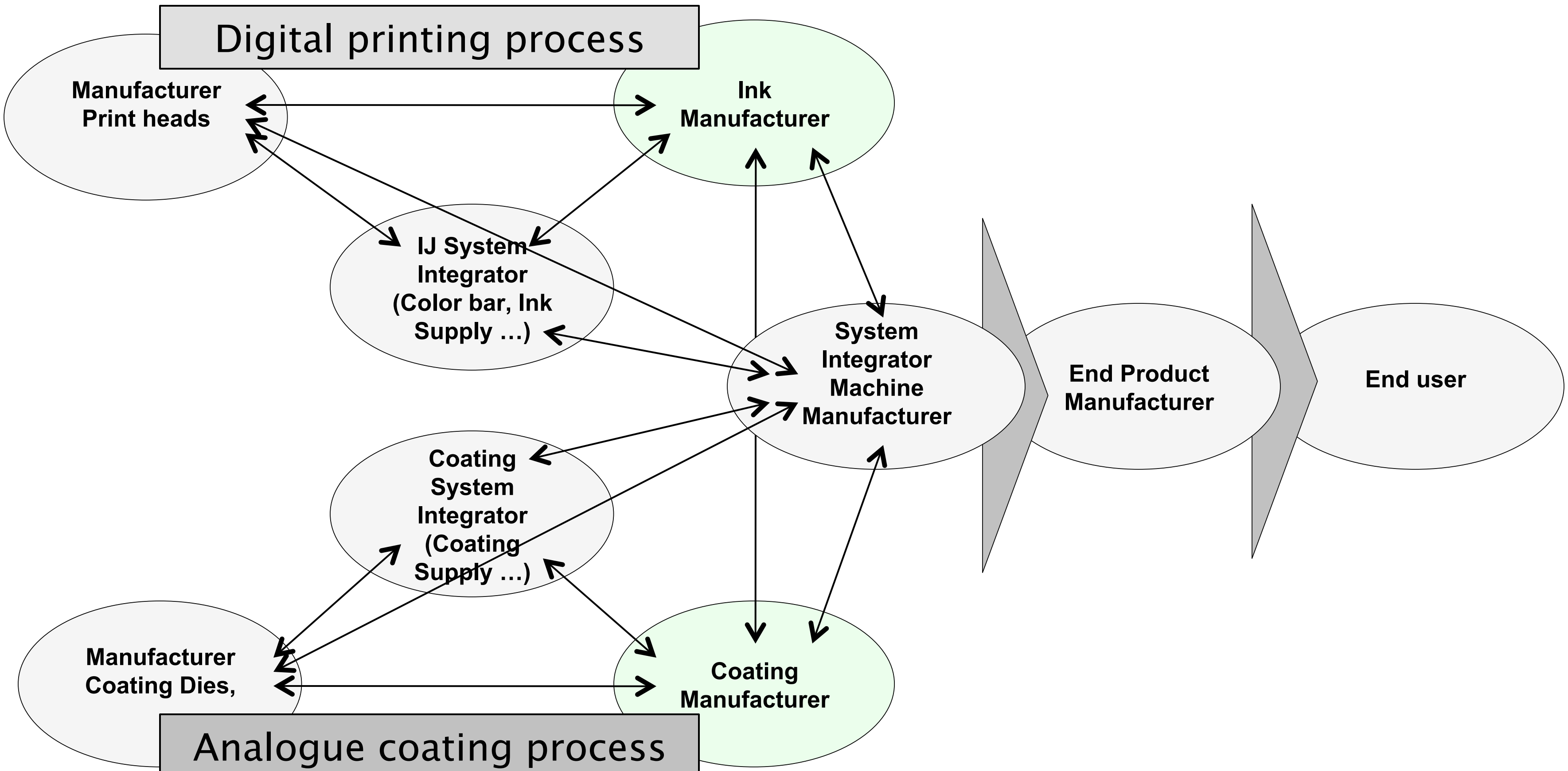
Starting from an existing industrial UV coating line

Designed by Bürkle

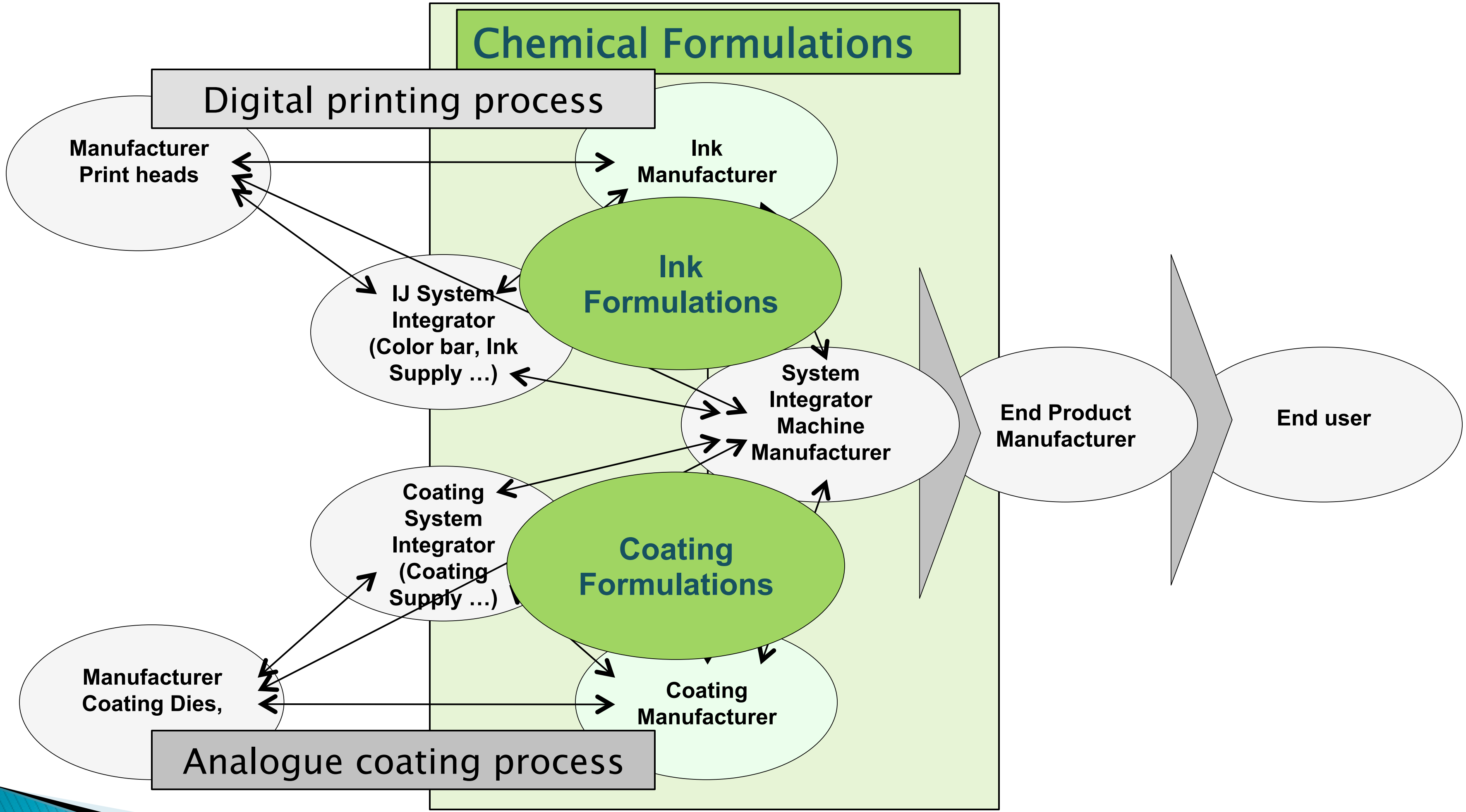
Integration of industrial UV coating line + digital printing unit …



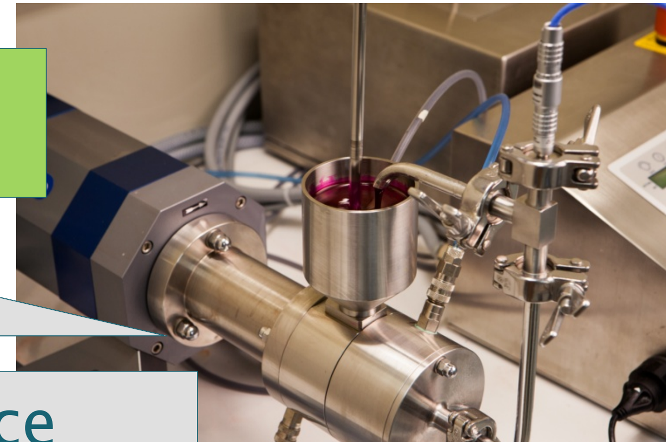
System integration: Interaction model



Interaction model:
The importance of chemistry



Ink formulation in a nutshell



High Performance nano dispersions

- Jetting performance
- End user requirements

Optimized carrier formulations

Nano dispersions of pigments

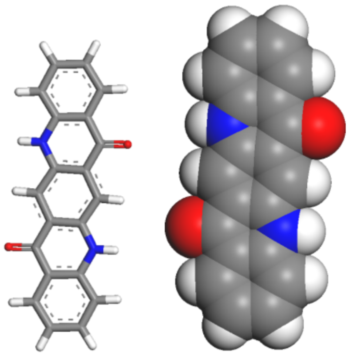
Inkjet needs:

- ➢ Nano sized dispersions:
  mean particle size < 200 nm
- ➢ No oversizers
- ➢ Stable in low viscosity formulations
- ➢ No sedimentation

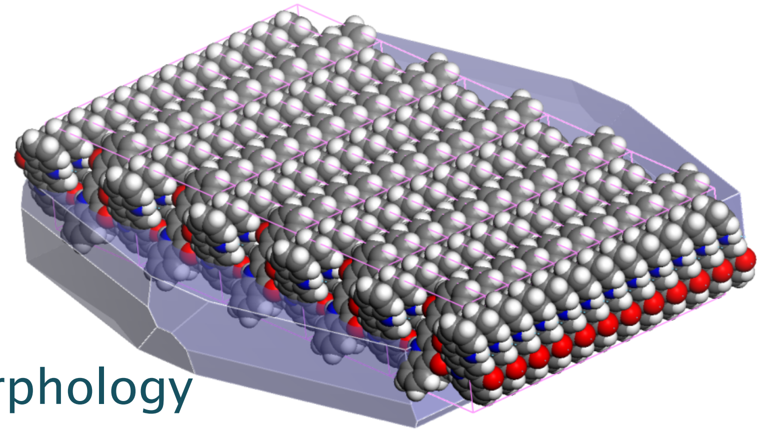
Milling process:
From raw pigment materials to nano dispersions

Dispersants:
Stabilizing agent to prevent re-agglomeration during printing process and shelf life

Interaction polymeric dispersants with crystal surfaces



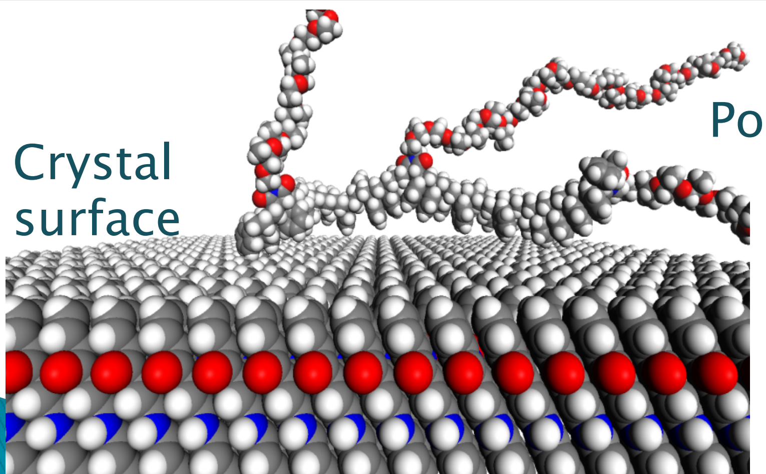
Molecular interactions



Molecular structure (Quinacridone)

Crystal Morphology

Crystal surface



Polymeric dispersant

Detailed molecular interactions between the dispersant and the crystal surface can be calculated with high accuracy

Interaction polymeric dispersants with crystal surfaces

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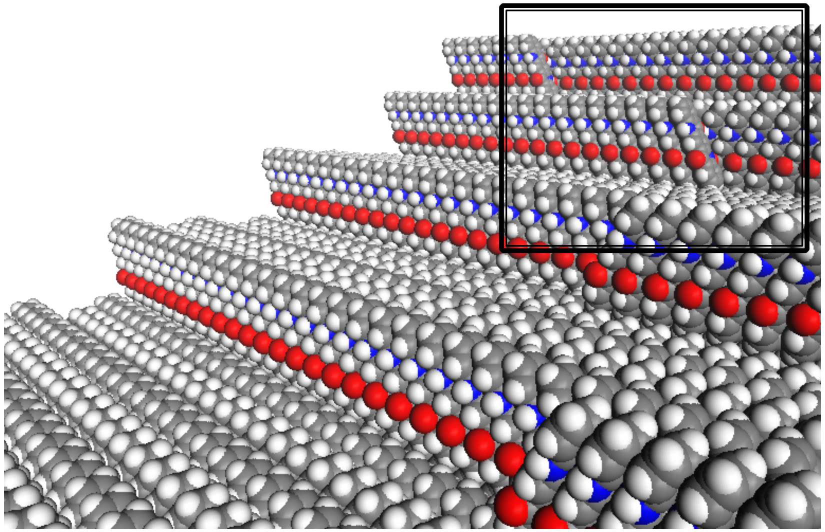
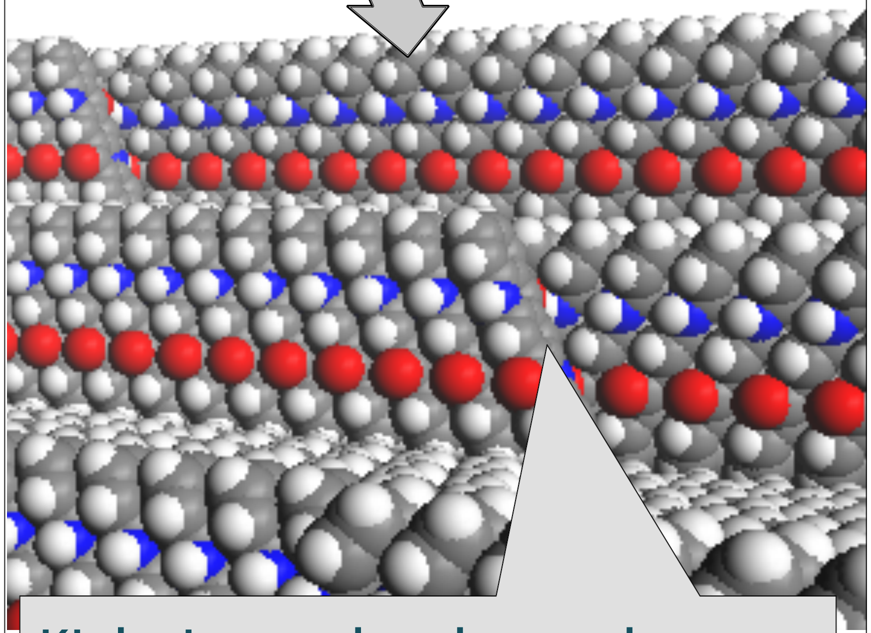


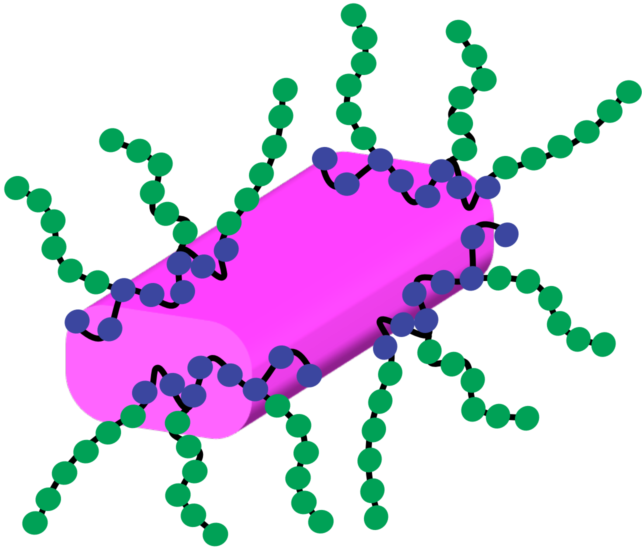
Real pigment world is even more exciting: crystal surface contains **steps and kinks**



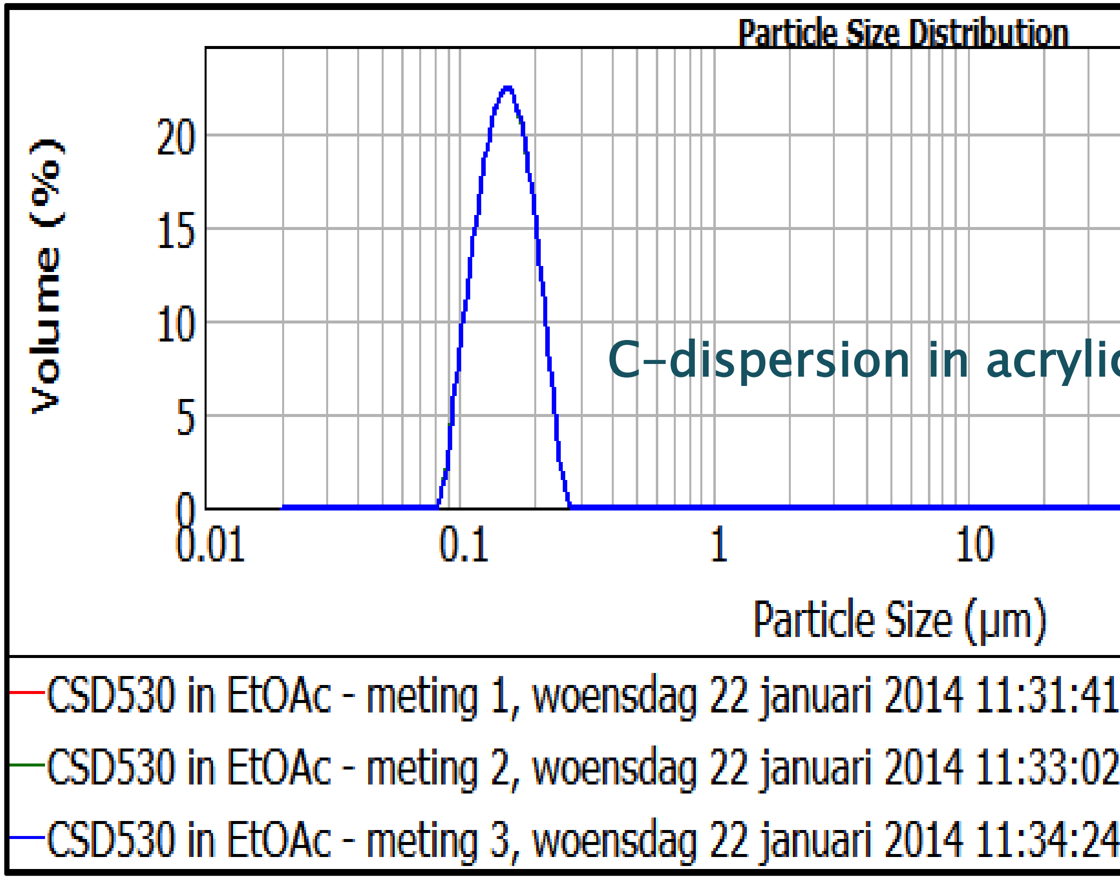
Kink sites = the place to be
“Anchoring” sites
“Receptor” sites
“Catalytic” sites

Polymeric dispersants with optimal architecture

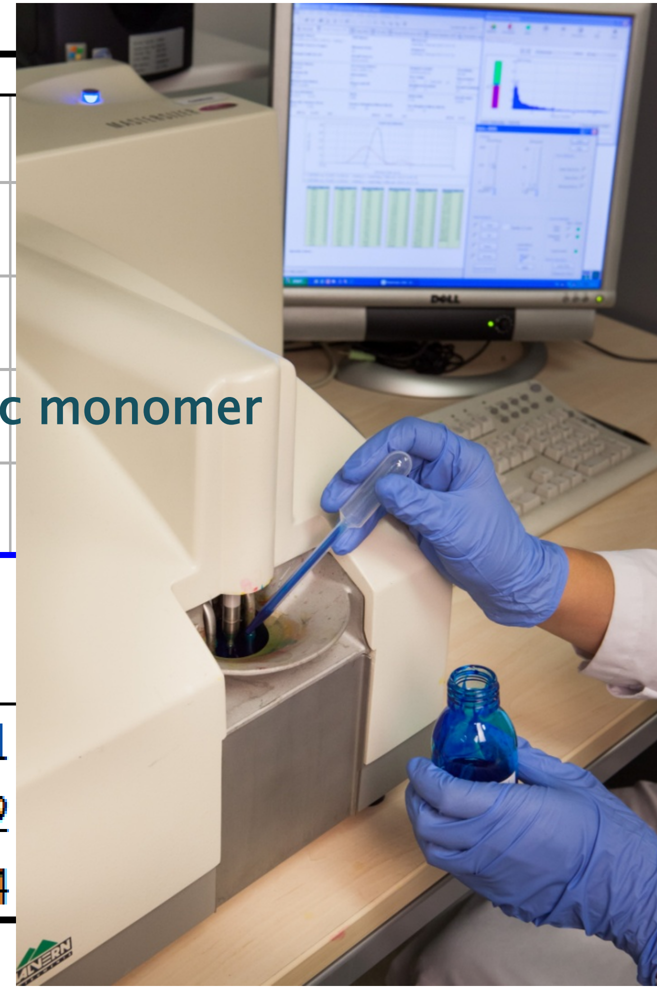
- Design the **pigment-anchoring chemistry** of the polymeric dispersing agent or redesign the **pigment surface**
- Design the **colloidal-stabilizing chemistry** of the polymeric dispersing agent
- Design the optimal architecture of the polymeric dispersing agent
- Synthesis of the polymeric dispersing agent / pigment particle surface
- Evaluation in nano dispersion of pigment



Stabilized nano dispersions
Particle size distribution



C-dispersion in acrylic monomer



Optimized carrier formulation

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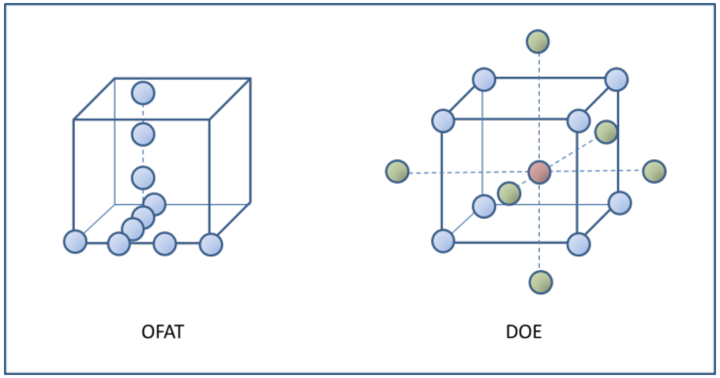
OFAT: One-Factor-At-a-Time

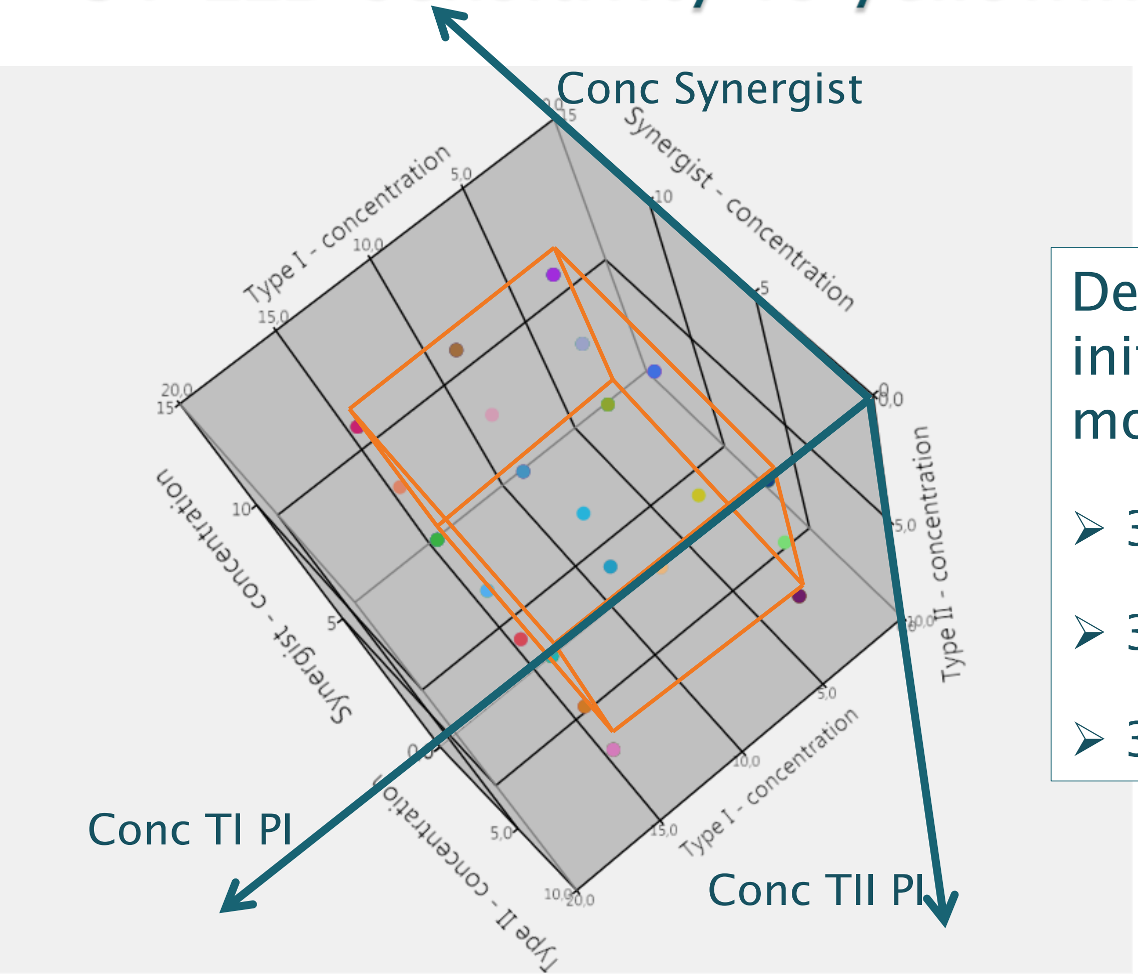
- Time consuming approach
- No interactions between various factors

DOE: Design Of Experiments

- Reduction of # experiments by combining factors
- Interactions between factors become visible.



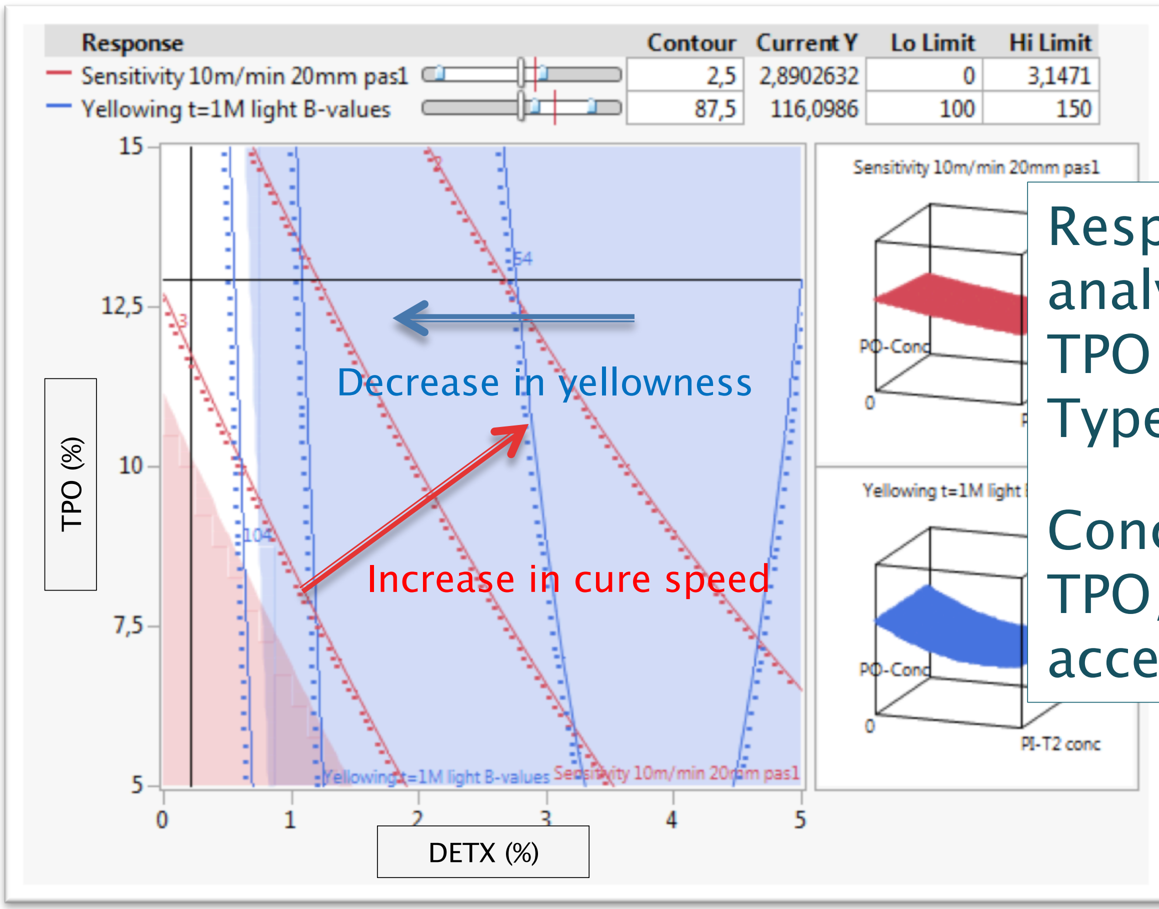
Case Study
UV LED sensitivity vs yellowing



Design space of photo initiators in a low viscous monomer system:

- 3 different Type I PI's
- 3 different Type II PI's
- 3 different Amine Synergists

Case Study
UV LED sensitivity vs yellowing



Responses and model analysis example:
TPO (Type I PI) and DETX Type II PI)

Conclusion:
TPO/DETX system only acceptable for pin curing

Integration of inkjet printing in an industrial process

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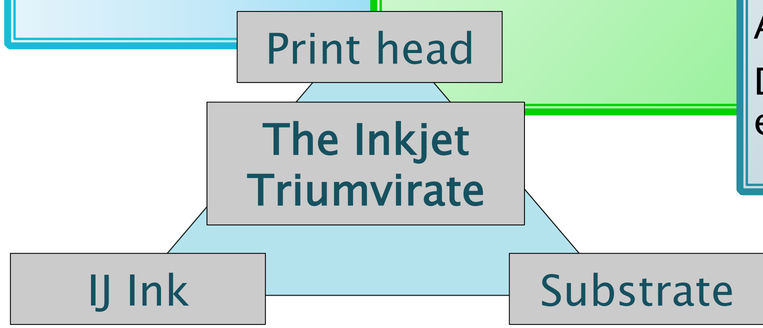
Inkjet ink
- Functionality
- Printhead
- Jetting performance
- Substrate
- Safety requirements

Printhead
- Print speed
- Ink composition
- Cost / nozzle
- Resolution / image quality

Printing set-up
- Substrate
- Speed
- Robustness
- Cost requirements
- Available space
- Drying/Curing equipment

Production Line



Integration of inkjet printing in an industrial process

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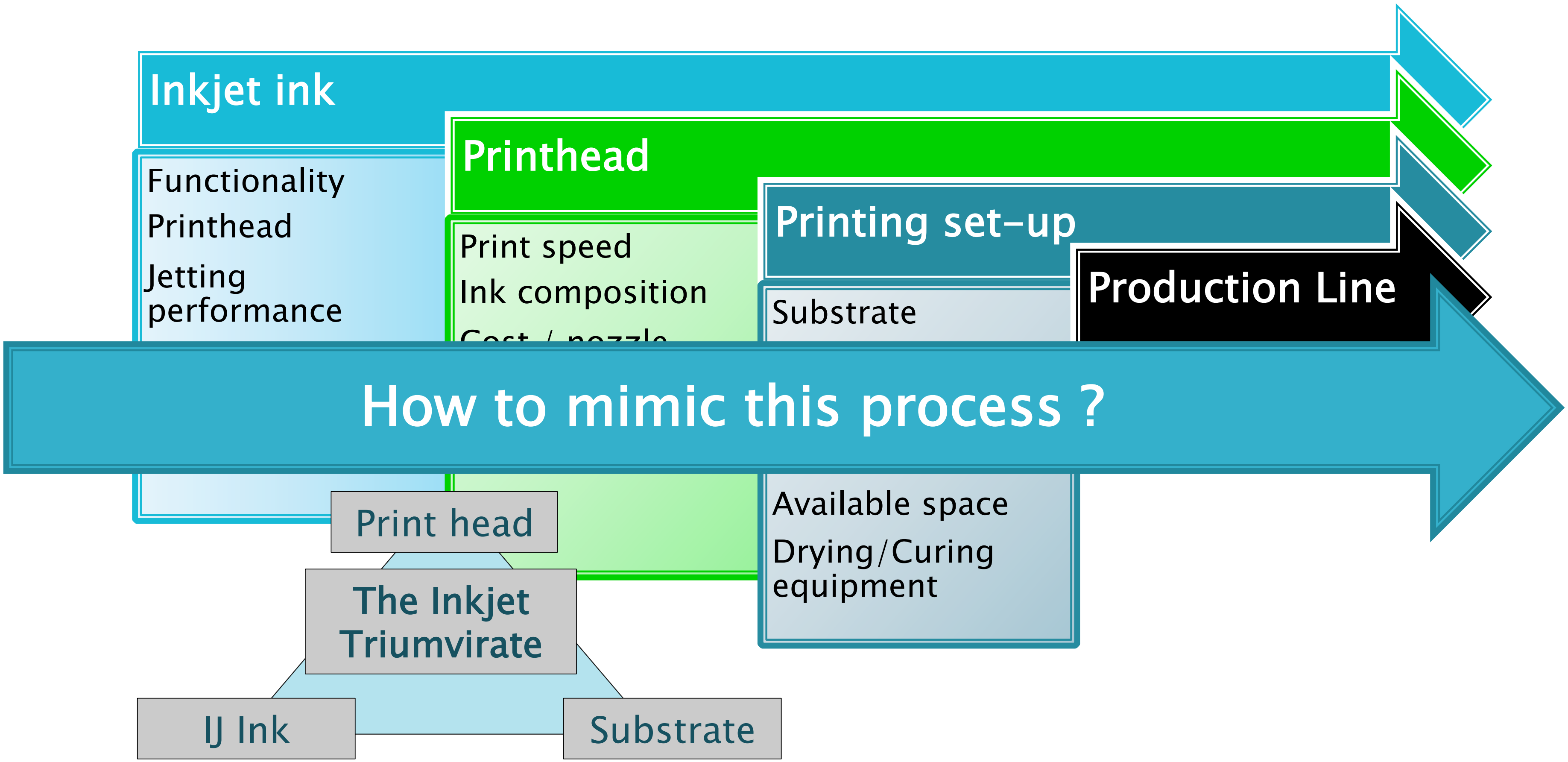

Modular Printing Unit – MPU

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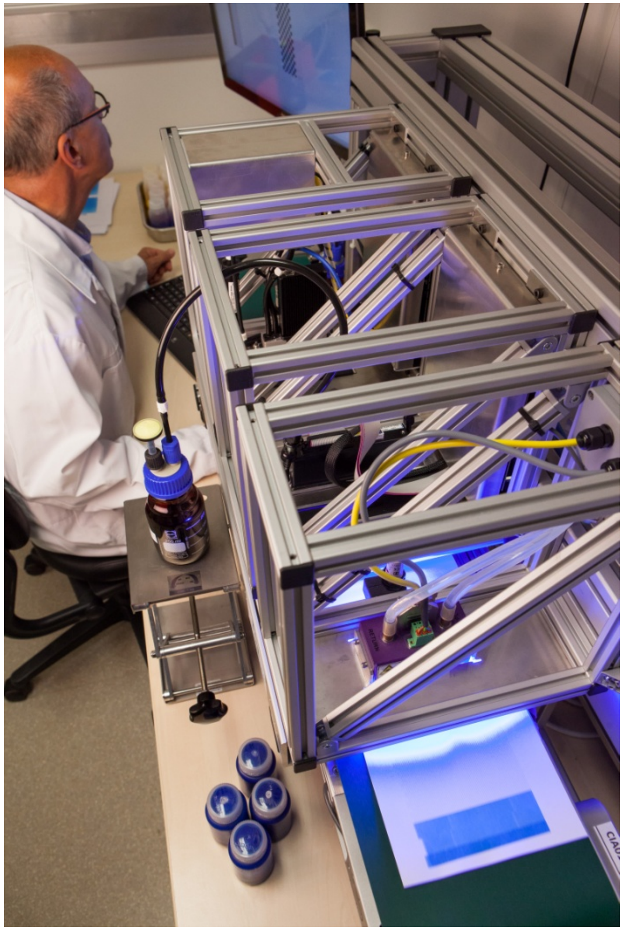
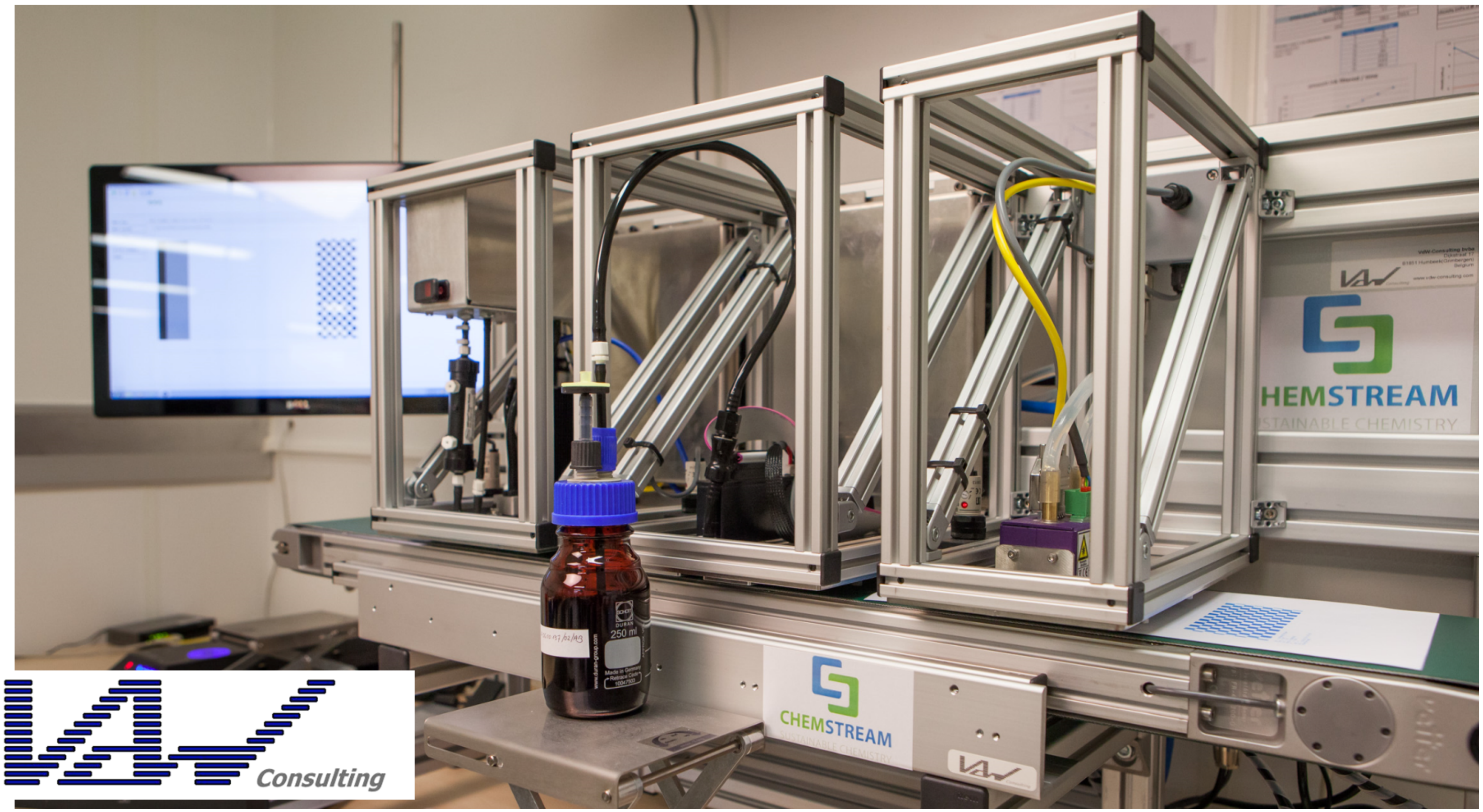
Features

- ‘Down to earth’ printing system
  - Table top dimensions
  - No special infrastructure
  - Belt based system for single pass
  - Potential for crude multi pass
  - Small ink amounts
- Flexible towards:
  - Head selection and replacement
  - Substrate height
  - Print strategies
  - Ink replacement



Modular Printing Unit – MPU



Modular Printing Unit – MPU

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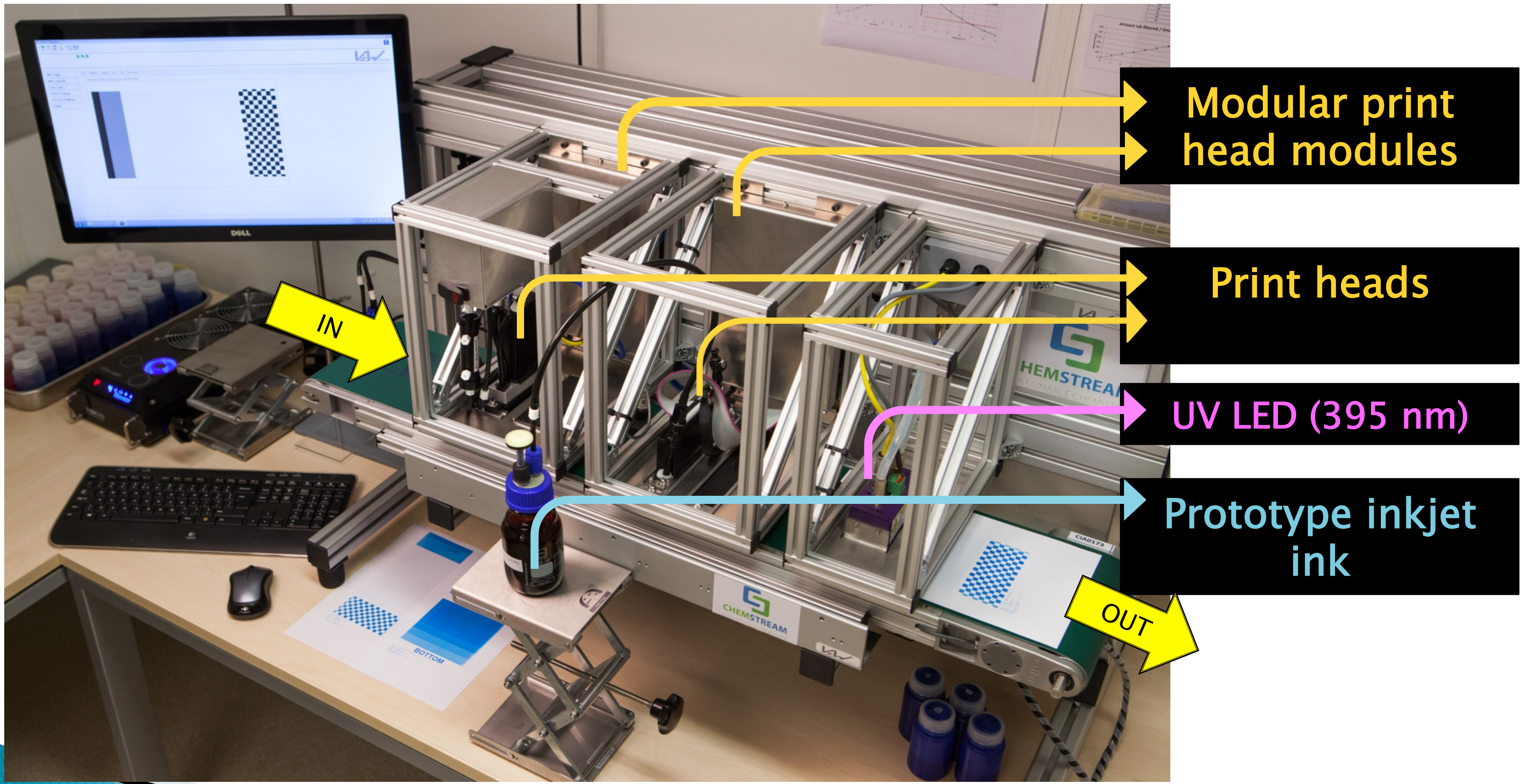
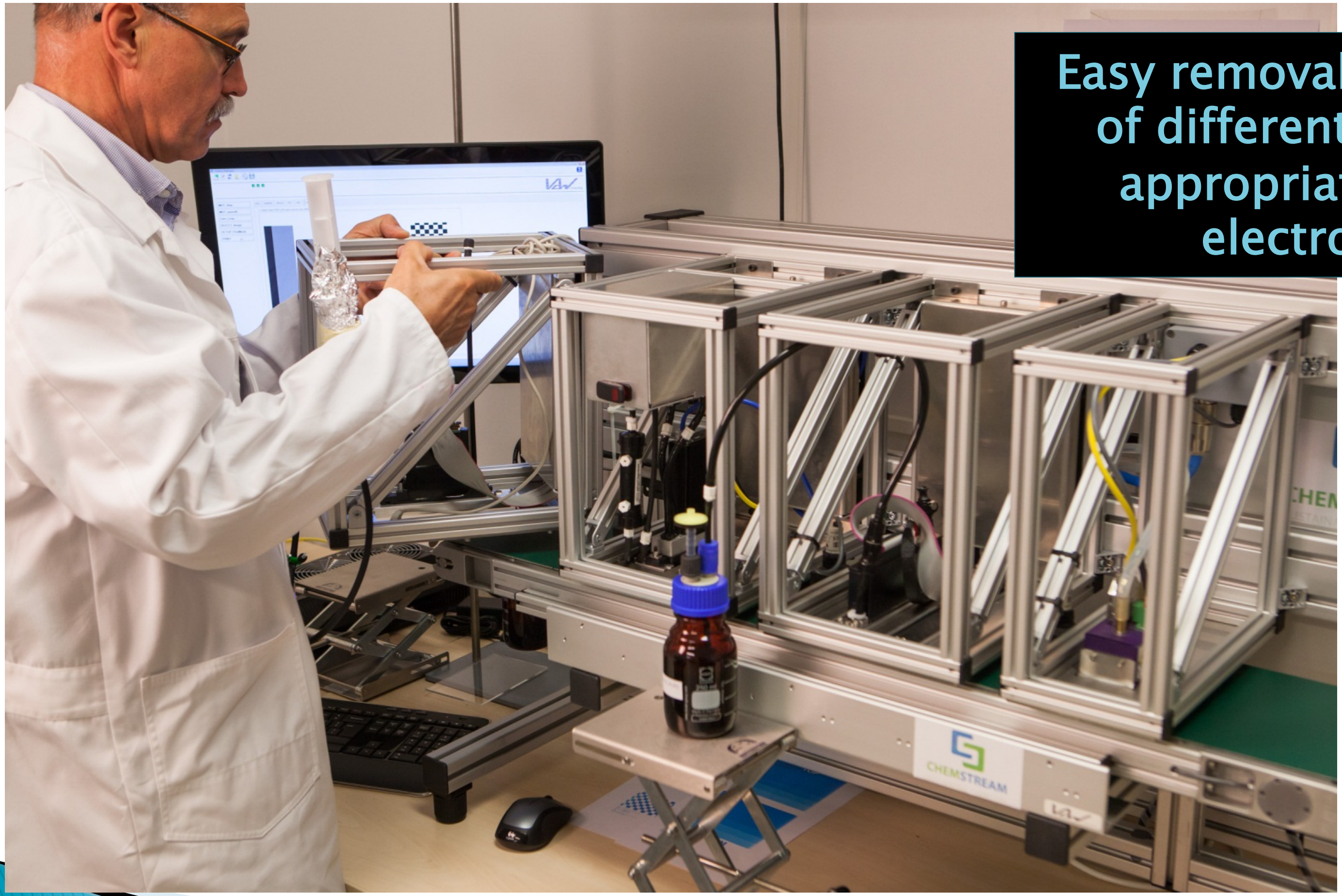


Modular Printing Unit – MPU



Easy removal / addition of different heads + appropriate driver electronics

Modular Printing Unit – MPU

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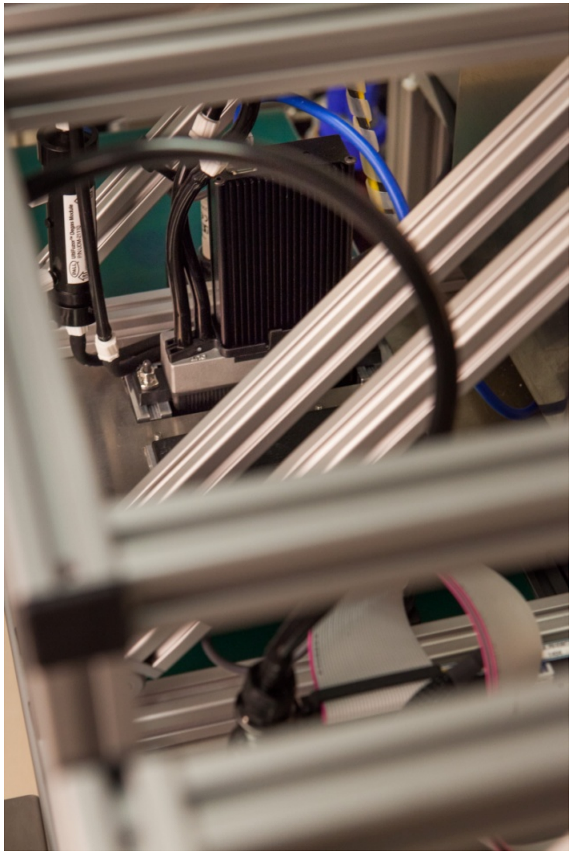
Advantages

- Easy tool for feasibility research
- Mimic of an in line coating/printing process
- Fast iterations of ink prototypes
- Fast iterations with different printheads
- Low investment level for customer
- Ink/media interactions
- Easy to provide test samples



Case Study: OLED-manufacturing
Thin film encapsulation (TFE)

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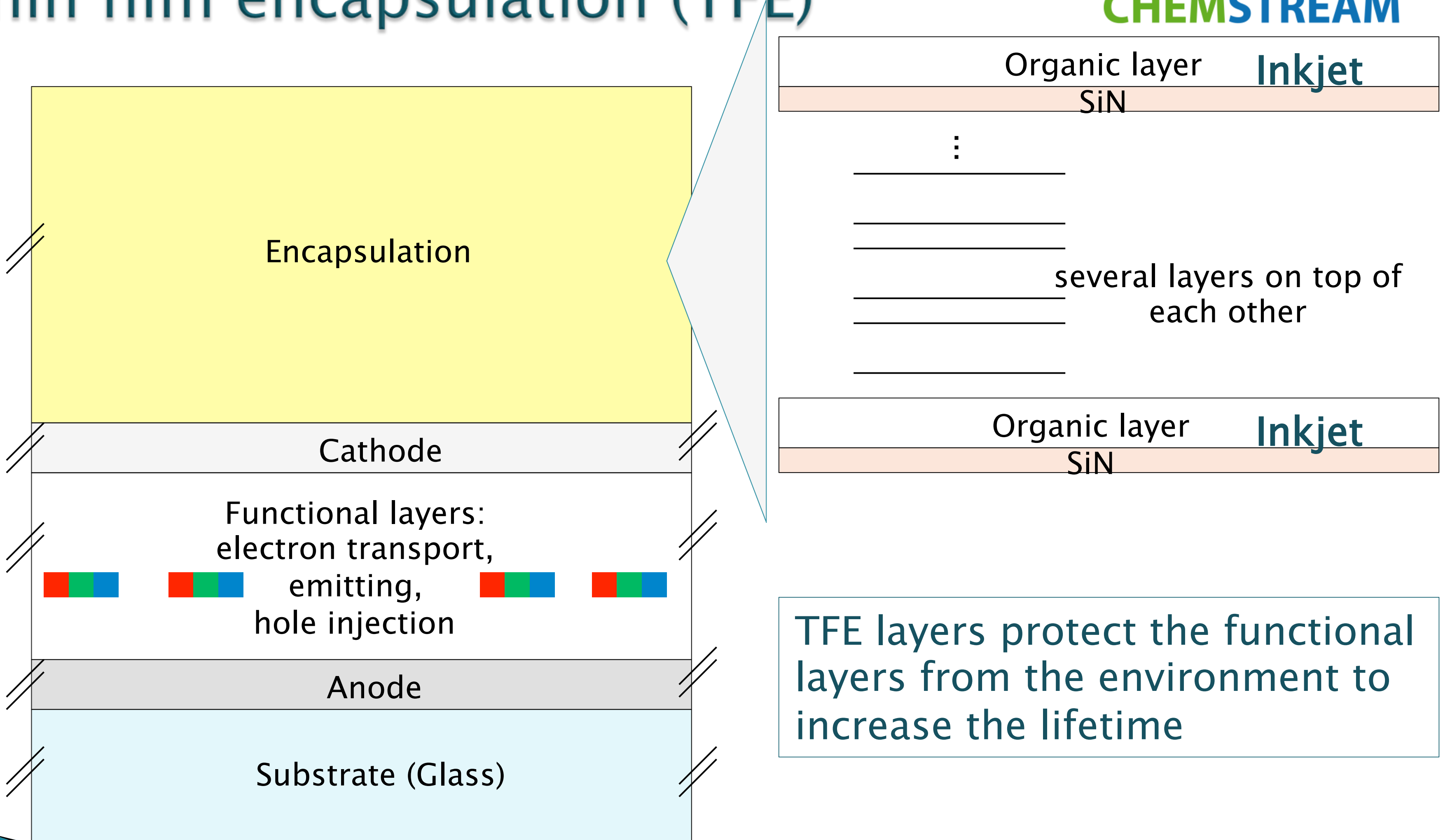

TFE layers protect the functional layers from the environment to increase the lifetime

Case Study:
Thin film encapsulation inkjet ink

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Main functional requirements of organic TFE layer:

- Layer thickness: 2-4 µm
- Water barrier properties
- Good adhesion on SiN
- Fast spreading and leveling properties
- UV Led curable (395 nm)
- High transmission in visible region
- No yellowing after aging

TFE Ink Design

UV LED curable carrier based on low viscous monomers and functional oligomers

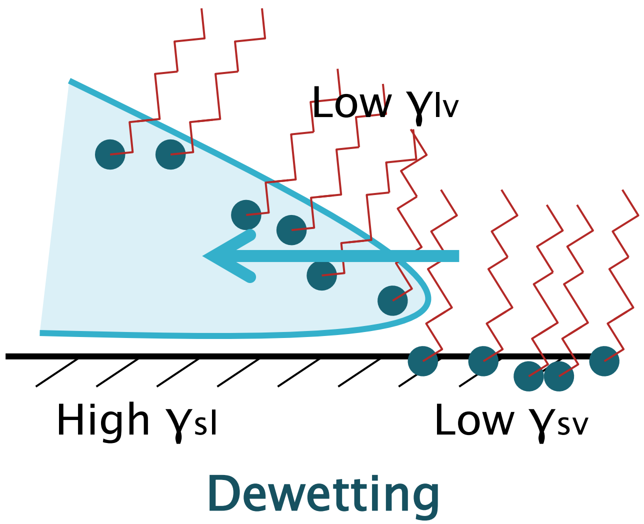
- Fast spreading and leveling
  - Full coverage with max 4 levels of gray scale head
  - Low viscosity: <10 mPas
  - Surface tension: 30 mN/m and no dewetting

- Cure Speed without yellowing
  - Low photoinitiator concentration

TFE Ink Design: Spreading on SiN

Wetting on high surface energy substrates like SiN

Depending on the strong specific interaction between the polar head of the surfactant and the substrate, the surface becomes more hydrophobic resulting in dewetting



Ink Design: Cure speed

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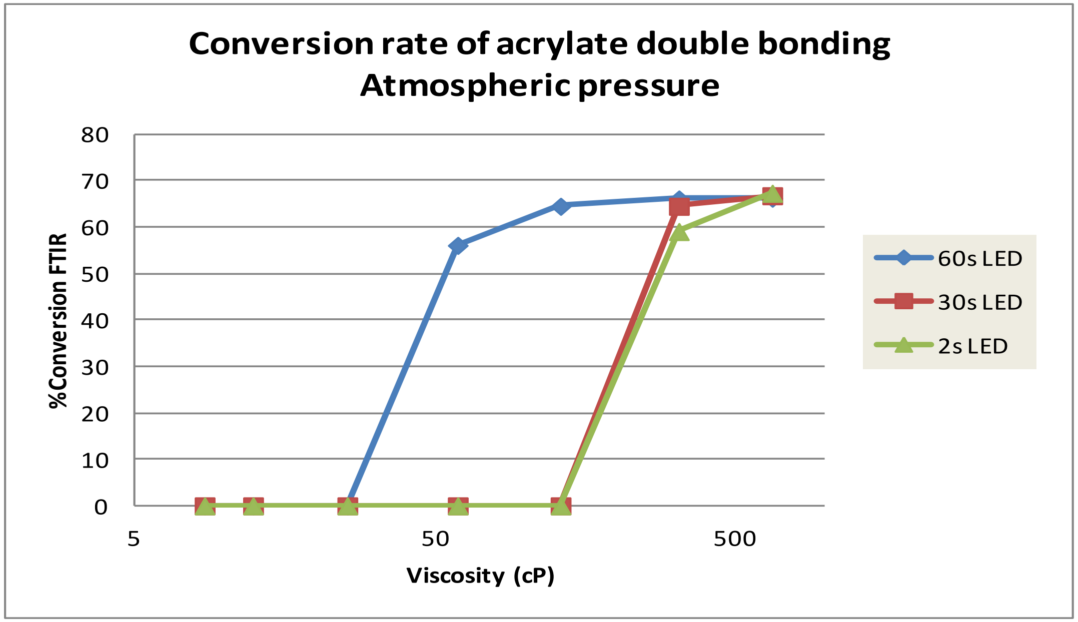
Oxygen inhibition has a negative influence on cure speed



Low viscosities are difficult to cure.
TFE ink: 10 mPas !

Thin films are difficult to cure.
TFE ink: 2-4 µm !

Oxygen diffusion penetration depth
δ = ±1 µm after 1sec
with (D= 10^{-6} cm²/s)

$$\delta \propto \sqrt[2]{D.t}$$

Ink Design: Cure speed

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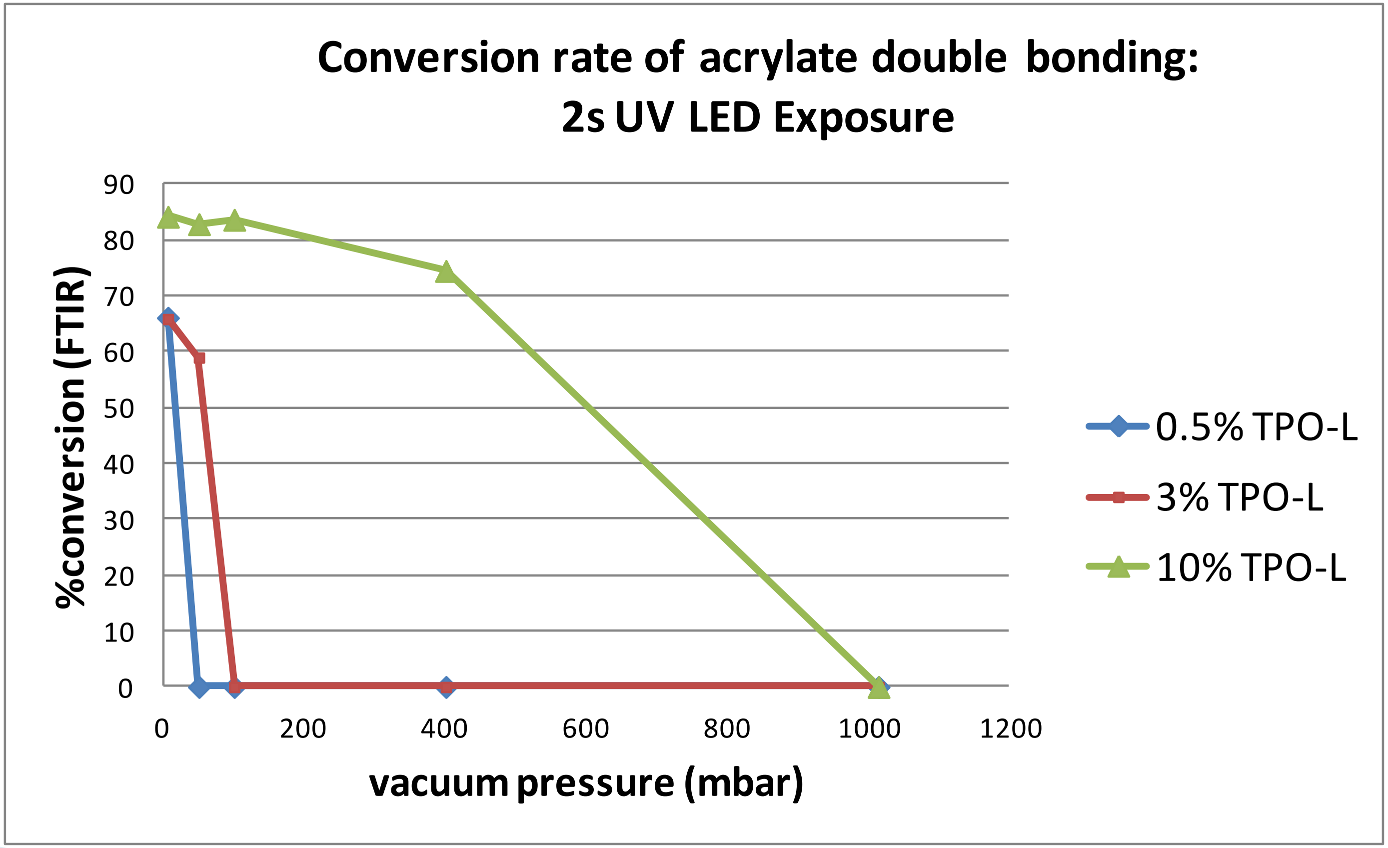
Curing in inert atmosphere increases the cure speed



TFE Ink Design: Conclusion

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Fast spreading and leveling without dewetting:

- Low viscosity
- Tuning the surface tension towards the surface energy of SiN
- Taking into account the interactions of surface active materials with the SiN-surface

High cure speed and full cure without yellowing

- Low PI concentration and well selected monomers
- Inert atmosphere (no oxygen inhibition)
- Digital printing unit was integrated in the TFE-line

Conclusion: High performance inkjet ink development

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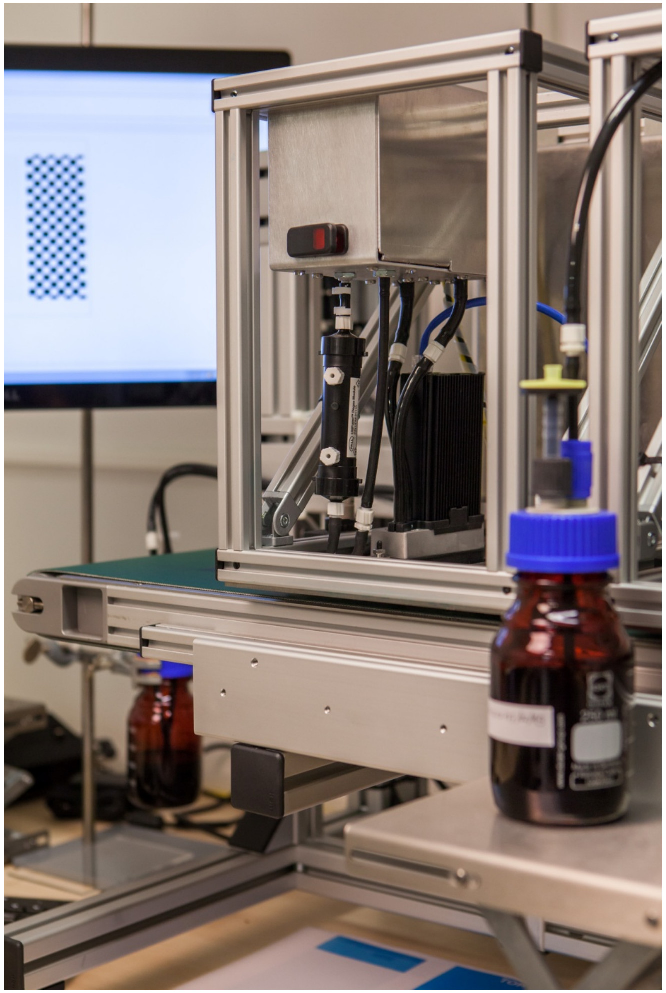

’Three in one‘ approach

- Fast prototype iterations
- Modular testrig approach:
- System integrated philosophy

Main features

- Short development times
- Customized approach
- Low investment level during feasibility phase

Thanks for your attention
More info on our website: www.chemstream.be