CHEMSTREAM
SUSTAINABLE CHEMISTRY

INDUSTRIALPRINTINTEGRATION

Inkjet 3D Printing

A groundbreaking tool for digital manufacturing

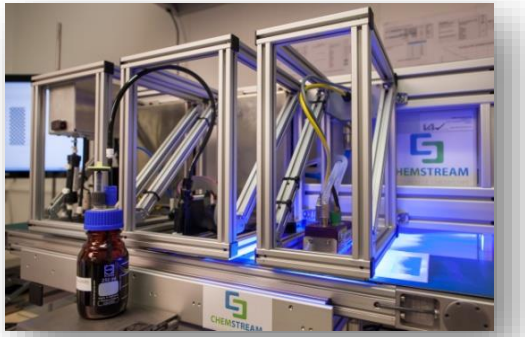
Dr. Els Mannekens
ChemStream

Chemstream: an independent Chemical R&D Company

- **Aim:** to develop innovative materials - from design to industrial prototype

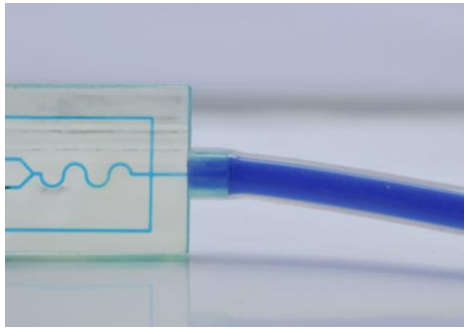
- **Core activities:**
  - Innovative contract research
  - Design and synthesis of (bio-based) functional chemistry (monomers, polymers, surfactants, adhesion promotors…) towards formulations

- **Main deliverables:**
  - **Inkjet inks**



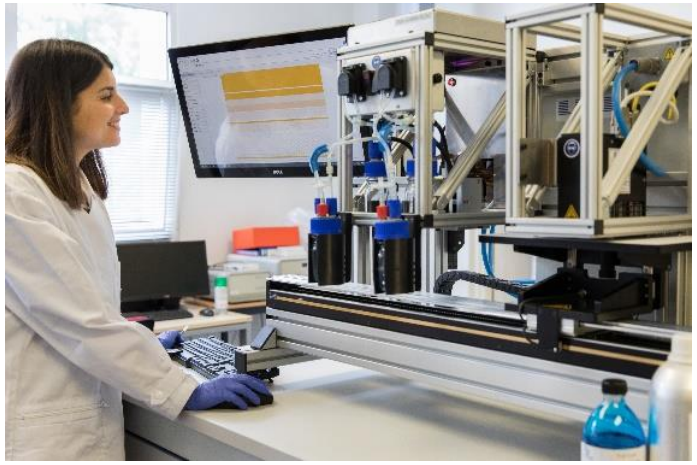
  - **Nano dispersions**

  - **Functional 3D printing materials**

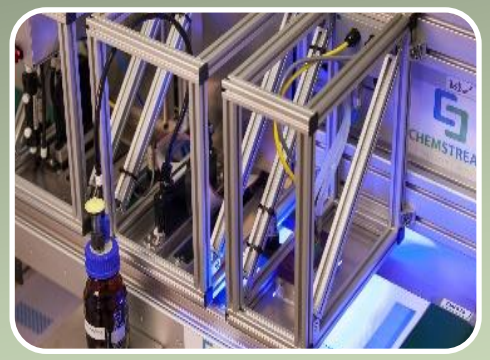


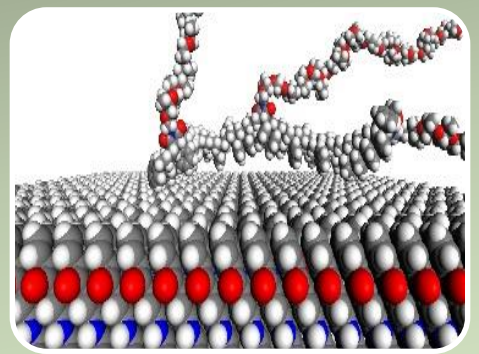
Chemstream: an independent Chemical R&D Company

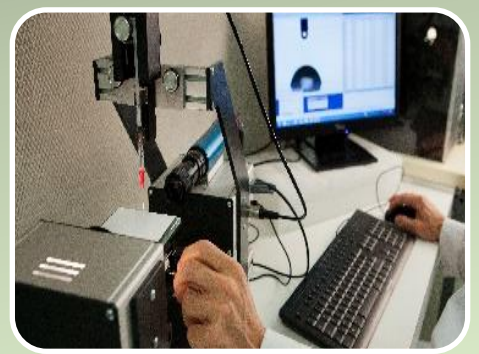
- **Founded in April 2010**
- **Staff profile (13 FTE, 10 PhDs)**
  - Chemistry (11)
  - Bio Engineer (1)
  - Material scientist (1)
- **Located near Antwerp – Belgium**
- **Lab-facilities (550 m²)**
  - Organic Synthesis
  - Chemical Formulation
  - Characterization
- **Prototype production facility**
  - Coatings: 250 L batches
  - Inkjet inks: 25 L batches



Chemstream: an independent Chemical R&D Company







Organic Synthesis

* Crystal, colorant and dispersant design
* Photochemistry
* Interfacial chemistry, wetting and adhesion
* Superabsorbent polymers
* Flow chemistry

Technology

* Dispersion technology
* Coating, printing, jetting (Modular printing unit MPU)
* Radiation curing (UV, UV-LED, e-Beam)
* Atmospheric plasma

Methodology

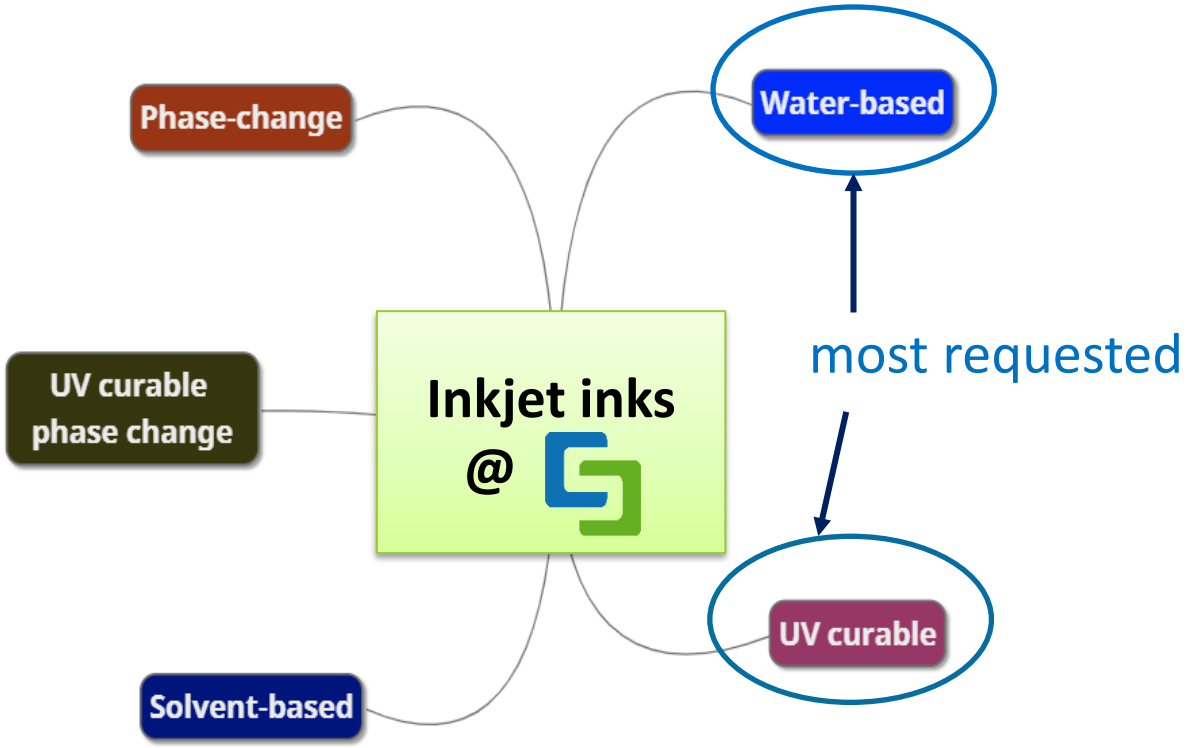
* Molecular modeling
* Design of Experiments (DoE)
* Smart throughput screening
* Hansen solubility parameters (HSP)

Analytical and physical chemical tools

* UVVIS, FTIR, GCMS, LCMS, GPC
* Particle size distribution (PSD)
* Contact angle, surface tension, viscosity

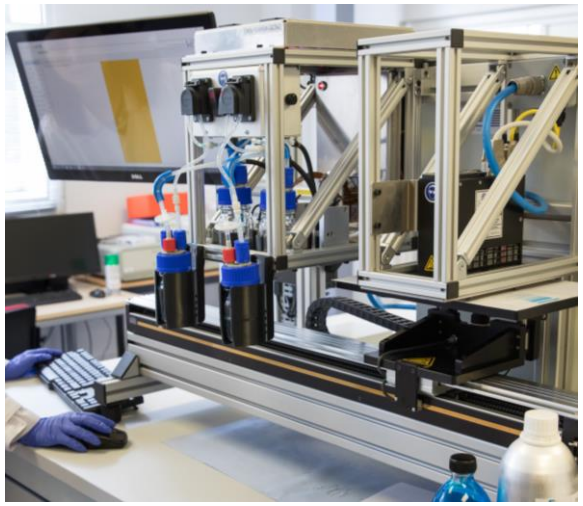
Chemstream: an independent Chemical R&D Company

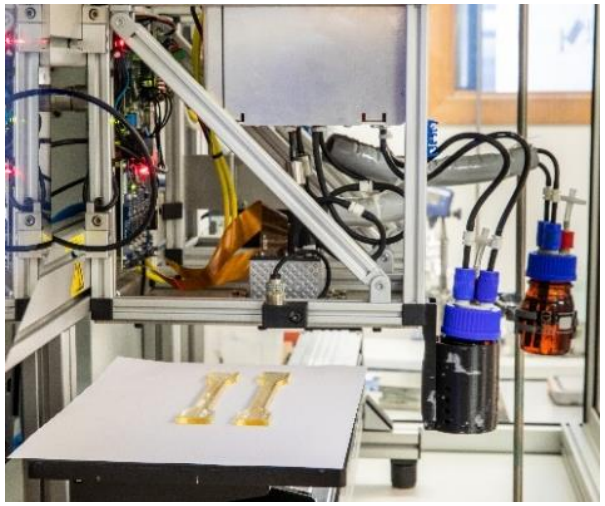
Inkjet @ ChemStream



Modular Printing Units

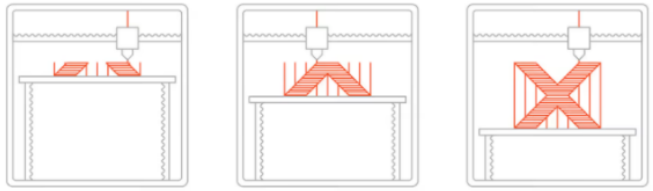
- ❑ Mimic of an in-line printing process
- ❑ Fast iterations of ink prototypes
- ❑ Different inkjet printheads





Main 3D printing techniques

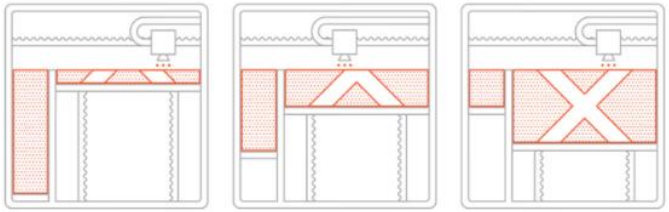
Material extrusion



FDM
FFF

Thermoplasts: PLA, ABS, PET, TPU, etc.

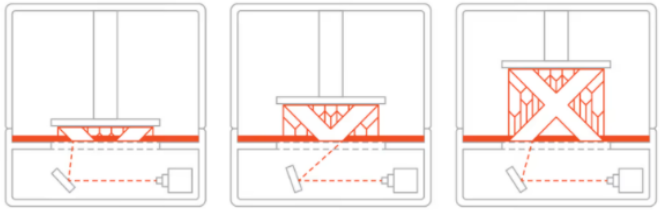
Binder jetting (in powders)



sand or metal powder, silica, PMMa

The binder can be jetted via inkjet technology

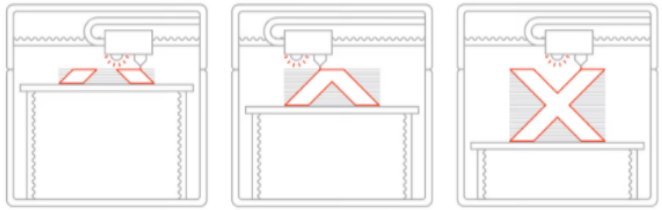
VAT (photo)polymerisation



SLA
DPL
MSLA

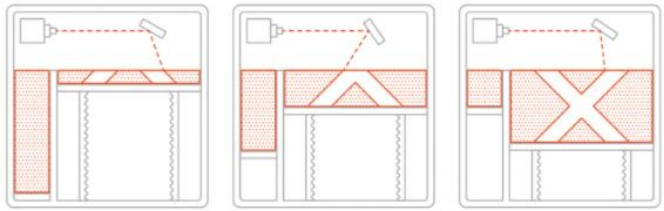
Photopolymer resins

Material jetting



DOD
PolyJet
NPJ

Powder bed fusion



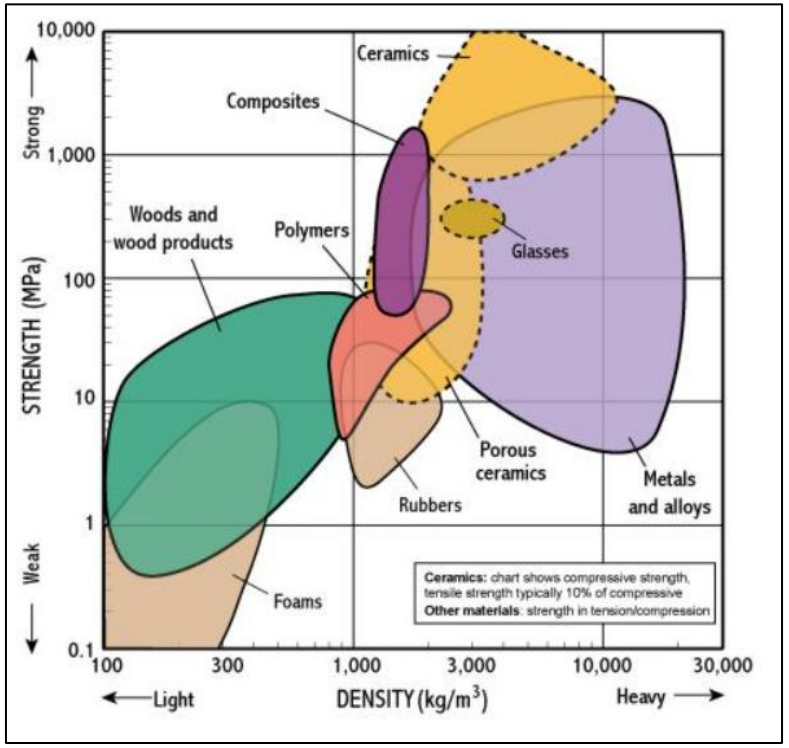
SLS
DMLS
SLM
EBM

Thermoploastic powders (Nylons)
Aluminium, stainless steel, titanium, etc.

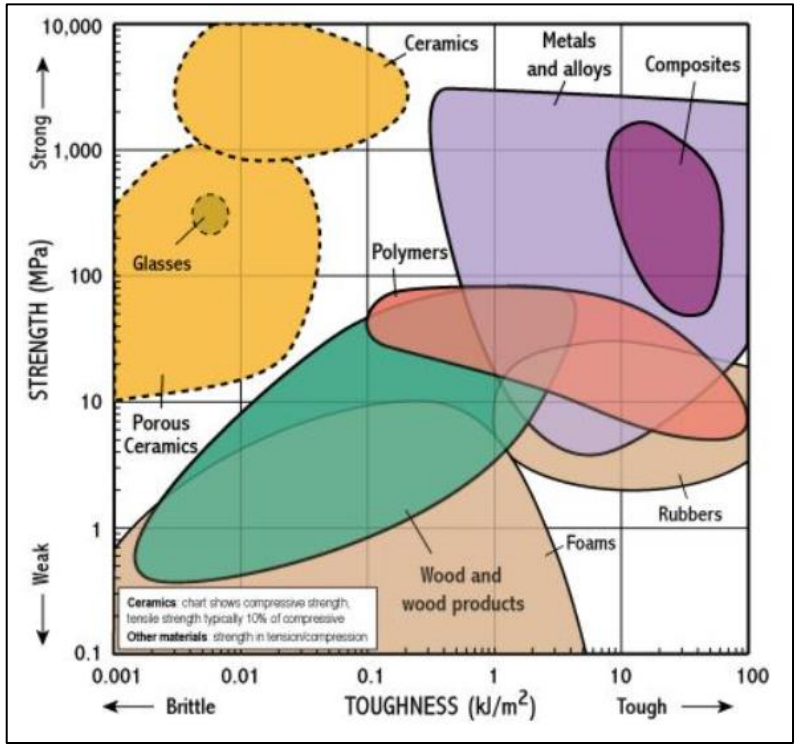
source: The 3D Printing Handbook

Main 3D printing techniques

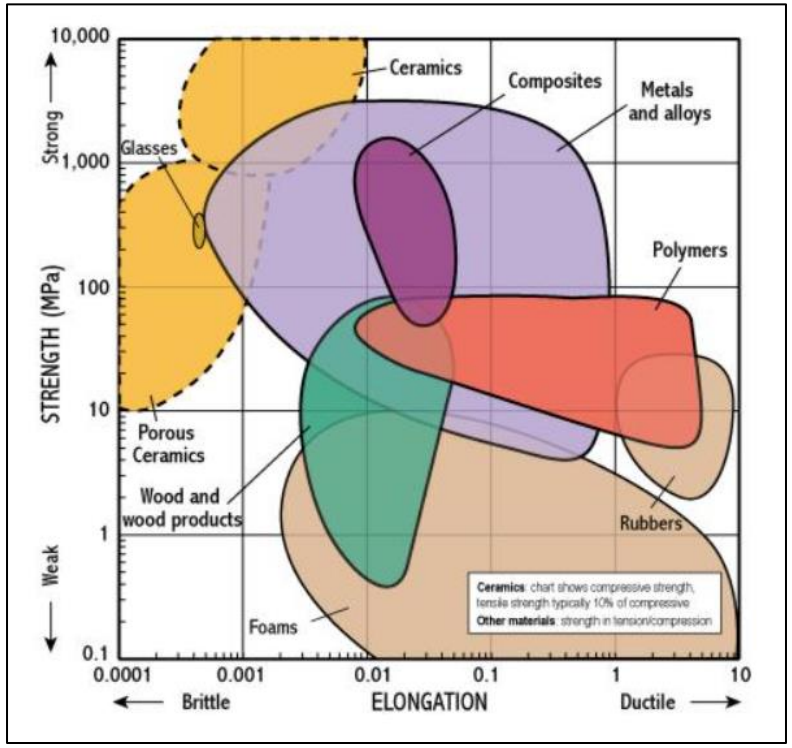
Material positioning



Strength vs density



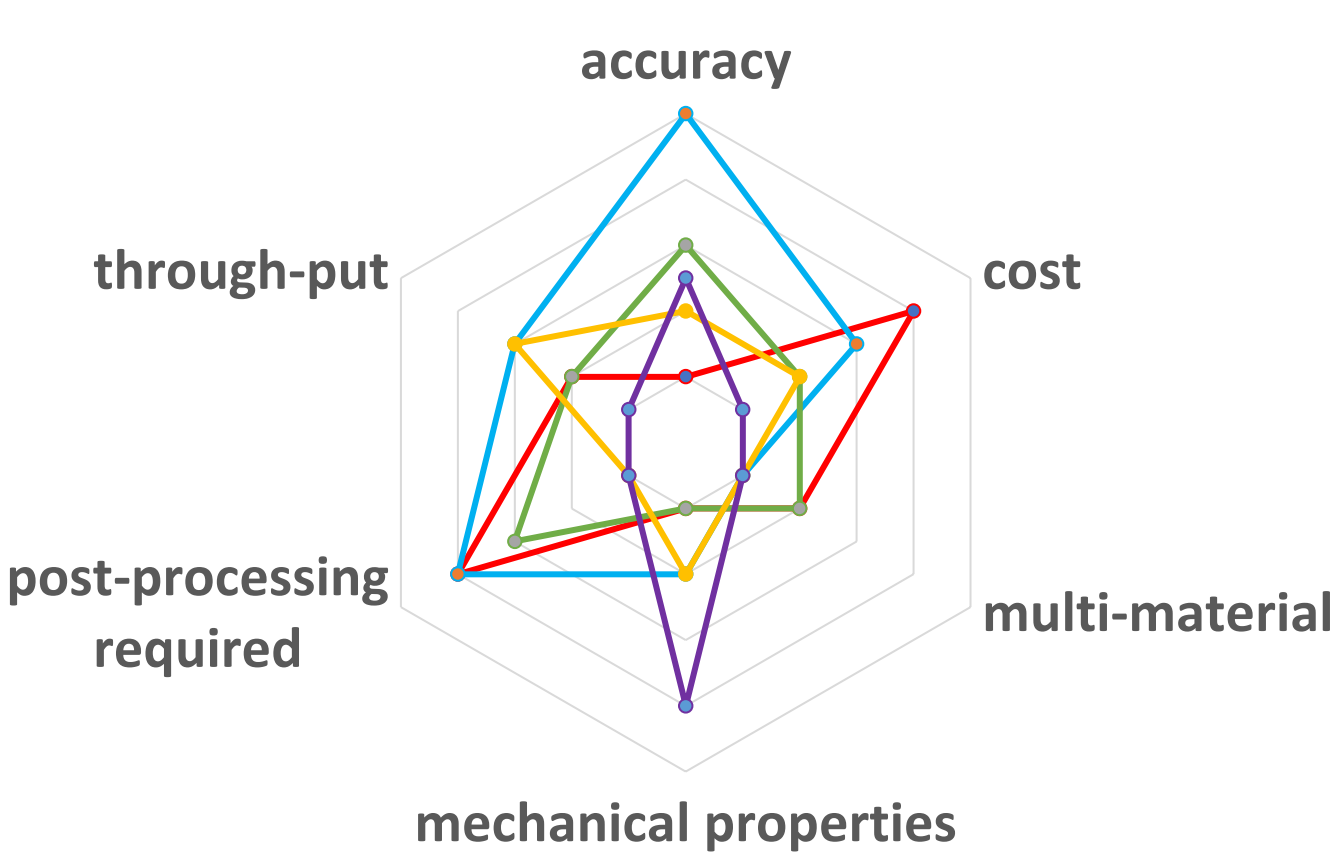
Strength vs toughness



Strength vs elongation

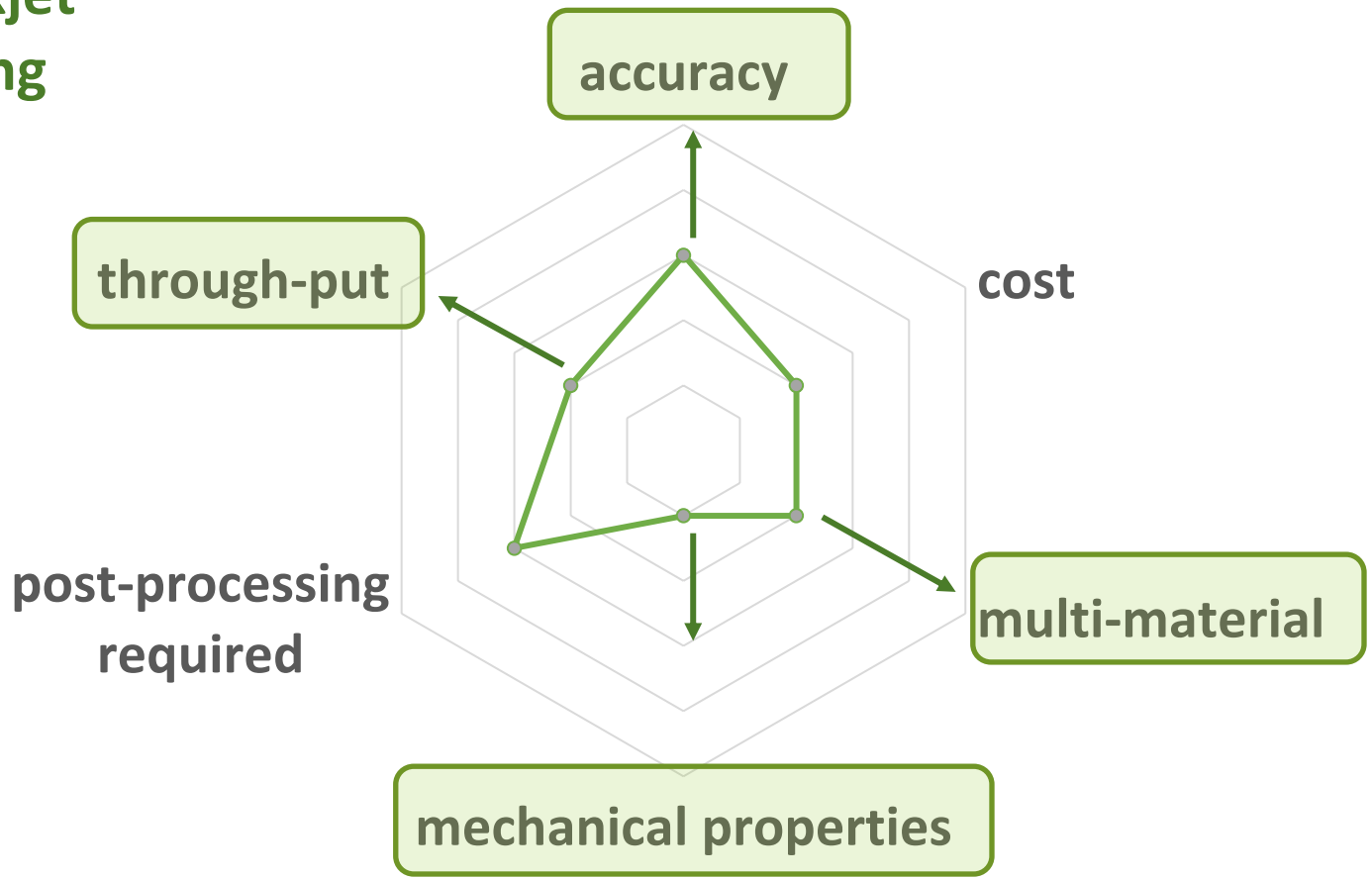
source: University of Cambridge, Dpt. of Engineering

3D inkjet printing



3D inkjet printing

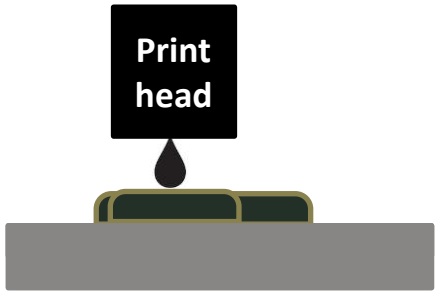
3D inkjet printing



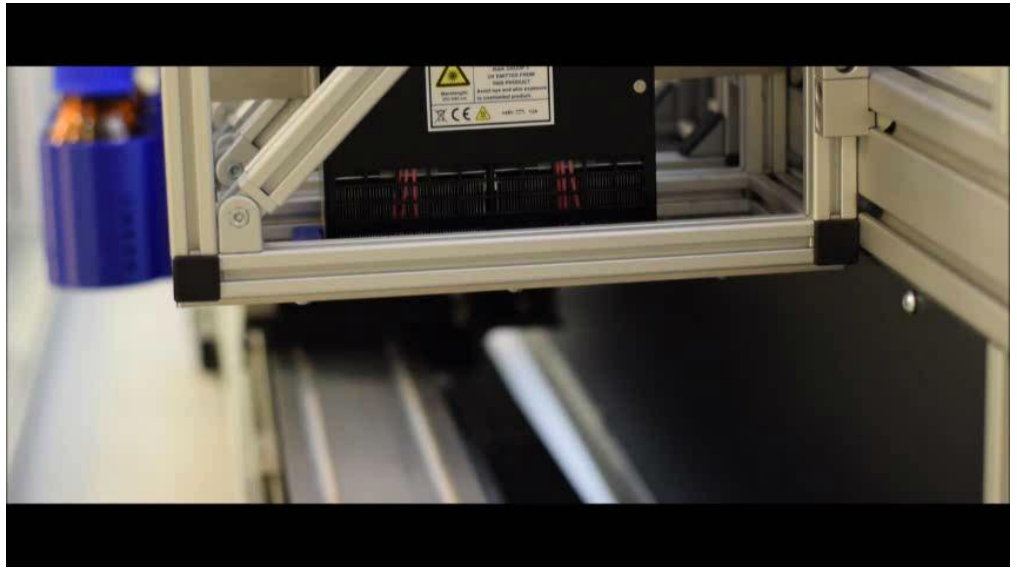
Room for improvement !

3D inkjet printing

Basic principle: 1 printhead, using 1 object ink



The inks are jetted and UV-cured, layer by layer



3D inkjet printing

Basic principle: 1 printhead, using 1 object ink

Ophtalmic lenses (OPTICAL application)

See: ink development for [Luxexcel's 3D printed lenses]

Importance:

- Ink parameters
  - Spreading of the ink
  - Ink-ink interactions
  - UV-sensitivity fine-tuning
  - Ink R.I.
  - Transparency
  - Non-yellowing
- Print parameters
  - Drop deposition design
  - Print speed
  - Curing power

Benefits:

- **Customized prescription lenses**
- No post-processing, no polishing required
- No waste of material
- Volume production
- Fast production process
  - Multiple-object printing
  - 1 printjob replaces about 30 traditional process steps

Through-put

3D inkjet printing

Basic principle: 1 printhead, using 1 object ink

Dogbones

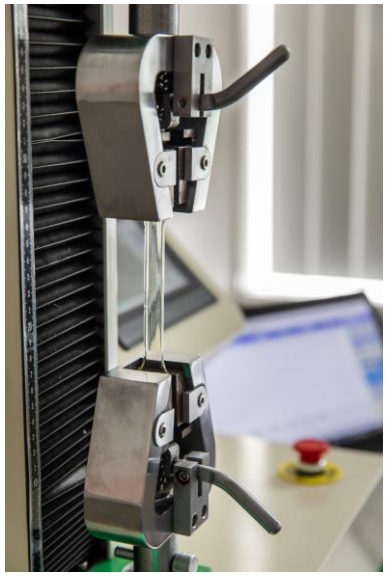
Importance:

- Ink parameters
  - Spreading of the ink
  - Ink-ink interactions
  - UV-sensitivity fine-tuning
  - Smart choice of building blocks
- Print parameters
  - Drop deposition design
  - Print speed
  - Curing power

Mechanical properties

Benefits:

- Design of new materials
- **Customized physical properties**



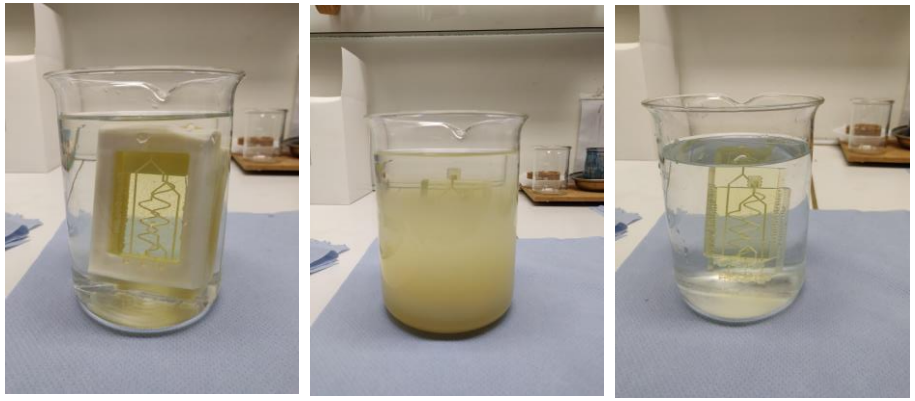
Molecular design toolbox

- ❑ Cross linking density
- ❑ Functionality side chain
- ❑ Functionality linker
- ❑ Intramolecular interactions

3D inkjet printing

Using 2 printheads (1 object ink + 1 support ink):

=> Support ink gets washed away after printing



ChemStream develops water removable support inks

3D inkjet printing

Using 2 printheads (2 object inks /1 object ink + 1 support ink):

Accuracy

Multi-material

Visual/Aestethic objects

Importance:

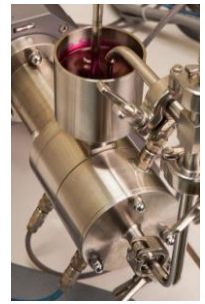
- Ink parameters
  - Spreading of the ink
  - Ink-ink interactions
  - UV-sensitivity fine-tuning
  - Transparency
  - Use of nano-pigment dispersions for color effects
- Print parameters
  - Drop deposition design
  - Print speed
  - Curing power

Benefits:

- Design of **customized 3D objects**
- Small to high volume production

Nano-pigment dispersion toolbox

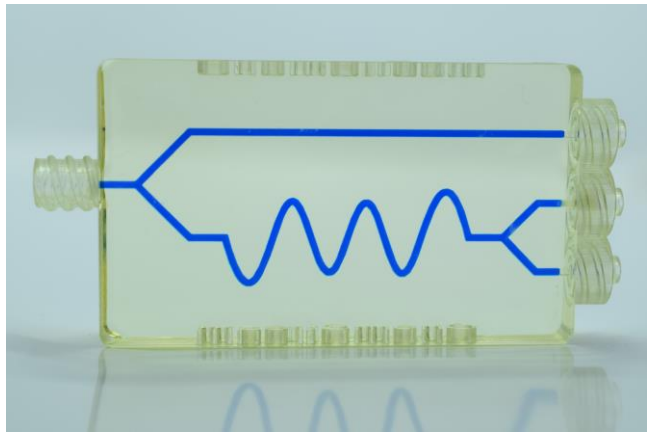
- ❑ Inkjet-quality pigments
- ❑ Fitting dispersion agents
- ❑ Milling expertise

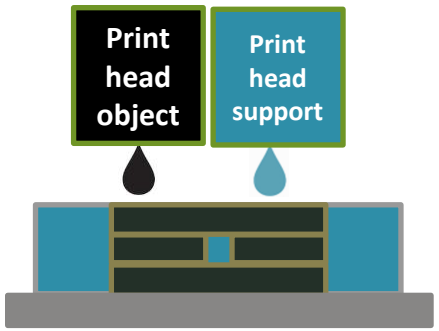


3D inkjet printing

Using 2 printheads (1 object ink + 1 support ink):

Functional objects (ex. Microreactors)





Importance:

- Ink parameters
  - Spreading of the ink
  - Ink-ink interactions
  - UV-sensitivity fine-tuning
  - Transparency
  - Easily removable support ink
- Print parameters
  - Drop deposition design
  - Print speed
  - Curing power

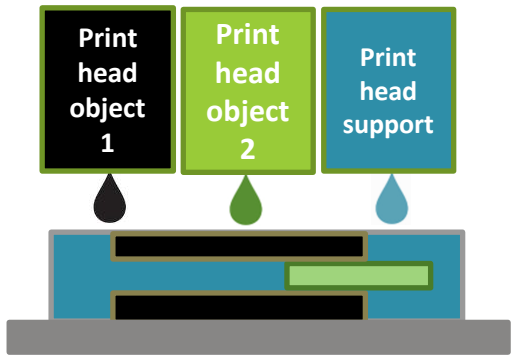
Benefits:

- **Unlimited design of microreactors**
- High accuracy, narrow channels
- Small to high volume production
- Fast production process: 1 printjob replaces a complex conventional production process

Through-put | **Multi-material** | **Accuracy**

3D inkjet printing

Using 3 printheads (2 object ink + 1 support ink):



=> Support ink gets washed away after printing

=> In inkjet it is possible to use even more printheads and ink types!

Multi-material | **Through-put**

Mechanical properties

Opportunities:

- **Unique designs of objects**
- Combination of structural design + mechanical properties variations in 1 object
- Embedded functionalities
- Small to high volume production
- Fast production process

3D inkjet printing

Multi-material | Through-put | Mechanical properties

High throuhput 3D inkjet manufacturing:

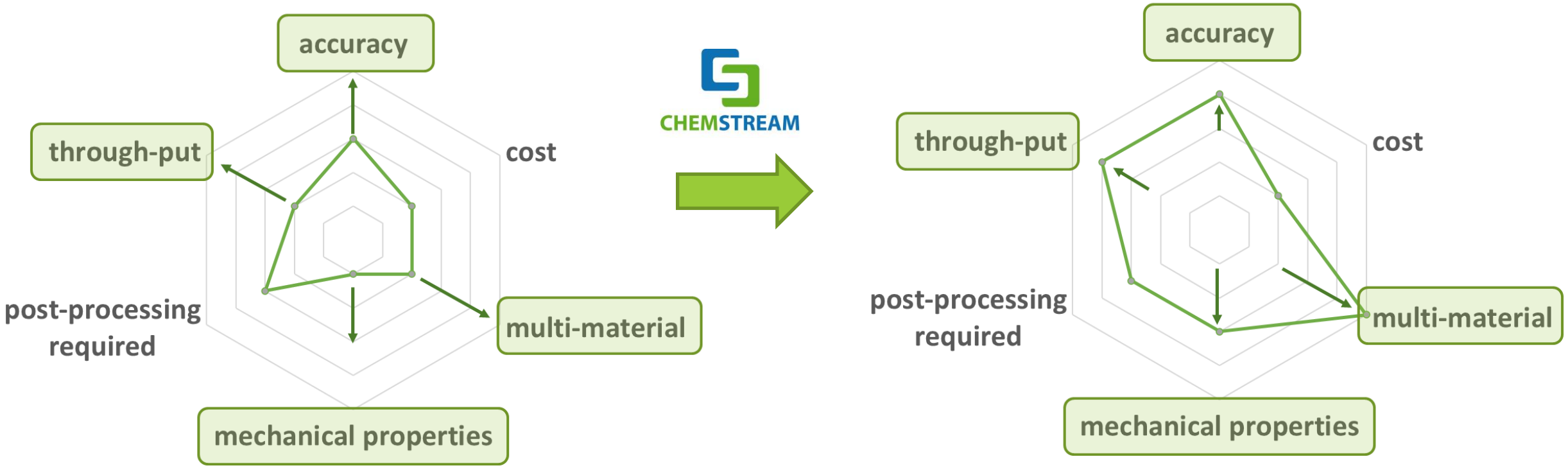
DP Polar – AM polar i1

- High Speed Rotative process (HSR)
- Multi-material printing
  - Variation in toughness
  - Variation in colours
  - Support ink soluble in water
- Print width = max. 420 mm (16,5 in)
- Layer thickness = 4-25 um
- Build resolution (xyz) = up to 720 x 720 x 5000 dpi
- Net Build Volume = 700 L
- Productivity= max 10 L/h

3D inkjet printing

High throuhput 3D inkjet manufacturing:

In conclusion:



3D inkjet printing

How can ChemStream support the development of such a process?

- Smart choice of UV-curable building blocks to obtain certain object specifications (physical properties, colour/transparancy, functionality,…)
- Fine-tuning of:
  - the inks for specific printhead compatibility
  - the ink-spreading characteristics
  - the ink-ink interactions
  - the colour of the inks (if necessary)
- Design of a compatible support ink
- Exploration and fine-tuning of the ink deposition process using in house modular printing units
- Producing inks to prototype level (up to 25L / ink batch)

For more info

CHEMSTREAM

come and see us @ Stand A4