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Evaluation of printability of screen- and pad printing inks via high-viscosity piezo inkjet technology

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Outline

Evaluation of printability of screen- and pad printing inks via high-viscosity piezo inkjet technology

1. Motivation
   Combining the advantages of screen-printing and inkjet rinting
2. Inkjet Printing
   Limitations
   Materials
   Printhead technology
   Material supply system
3. Qualifying materials for Inkjet Printing
   Process parameters
   Results
4. Outlook

Motivation

[Fahnen-Gärtner]

- Project partner:

  Ritzi Industriedrucktechnik

- Objective is the use of widely used **screen-printing inks** with the advantages of **digital printing techniques**

Limitations of screen-printing

- Analogue process
- High material and solvent usage
- Shortage of skilled workers
- Long setup times

Inkjet Printing

State of the art – Benefits and Limitations

Benefits

- Digital process
- Resource saving
- No setup times
- Contactless
- Scalable process

Limitations

- Limitation in materials through viscosity
- Nozzle diameter limits ejection of bigger particles

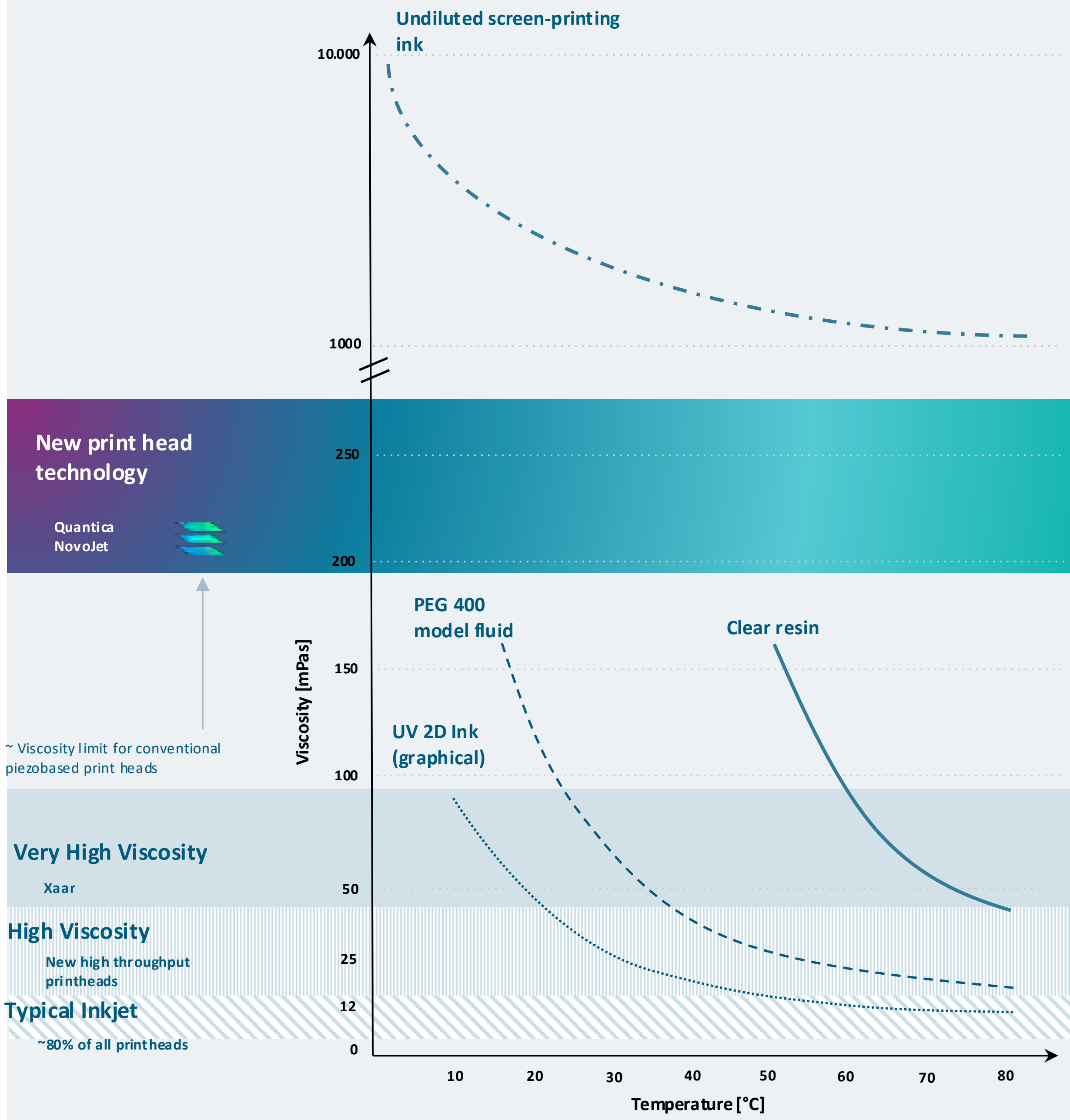
Current piezo based printhead technology was not developed and optimized for high viscosity printing

Inkjet Printing

Materials

Why was inkjet printing not yet used to process screen-printing inks?

- Viscosities of undiluted **screen-printing inks** of roughly **10.000 mPa*s** at room temperature
- Majority of **inkjet** printheads to date have a process window of up to **12 mPa*s**
- **New** printhead **technology** opens process window for **diluted** screen-printing inks



Inkjet Printing

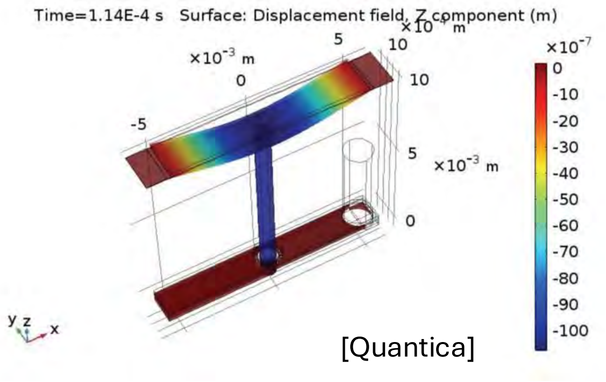
New printhead technology

	Quantica NovoJet™	Conventional Printheads[1]
Nozzle Count	96	128 - over 1000
Nozzle Diameter	50 µm (90 µm in testing)	5 – 20 µm
Jettable Particles (d90)	5 µm (tested)	< 1 µm
Droplet Volume	150 pl – 300 pl	5 – 100 pl
Native Resolution	20 DPI	50 – 1080 DPI
Fluid Viscosity Range (Jetting temp)	1 mPa*s – 250 mPa*s	5 - max 100 mPa*s
Jetting Temperature	RT – 80 °C	RT – 80 °C
Frequency	8 kHz	30-50 kHz
Surface Tension	30-750 mN/m	20 – 30 mN/m

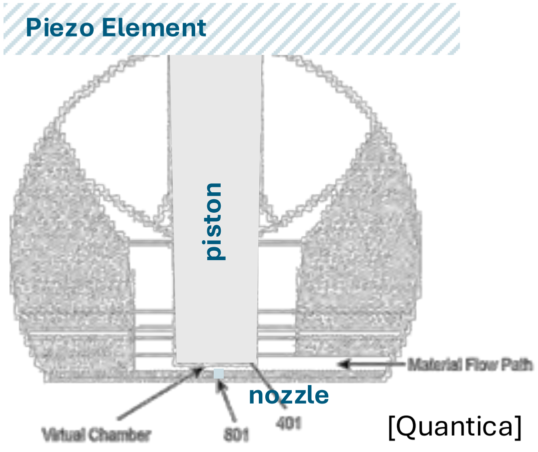
[1]Range indication across different vendors and printhead types: Absolute numbers dependent on the actual printhead model | type

Quantica NovoJet™

Displacement simulation



[Quantica]



[Quantica]

- **Large actuator displacement** - 100x more than conventional printheads

Potential for a lot new materials to be printed with this technology to exploit new applications and markets

Due to the new working principle of the printhead, are the existing process characterization for piezo inkjet printing still valid for the NovoJet™ technology?

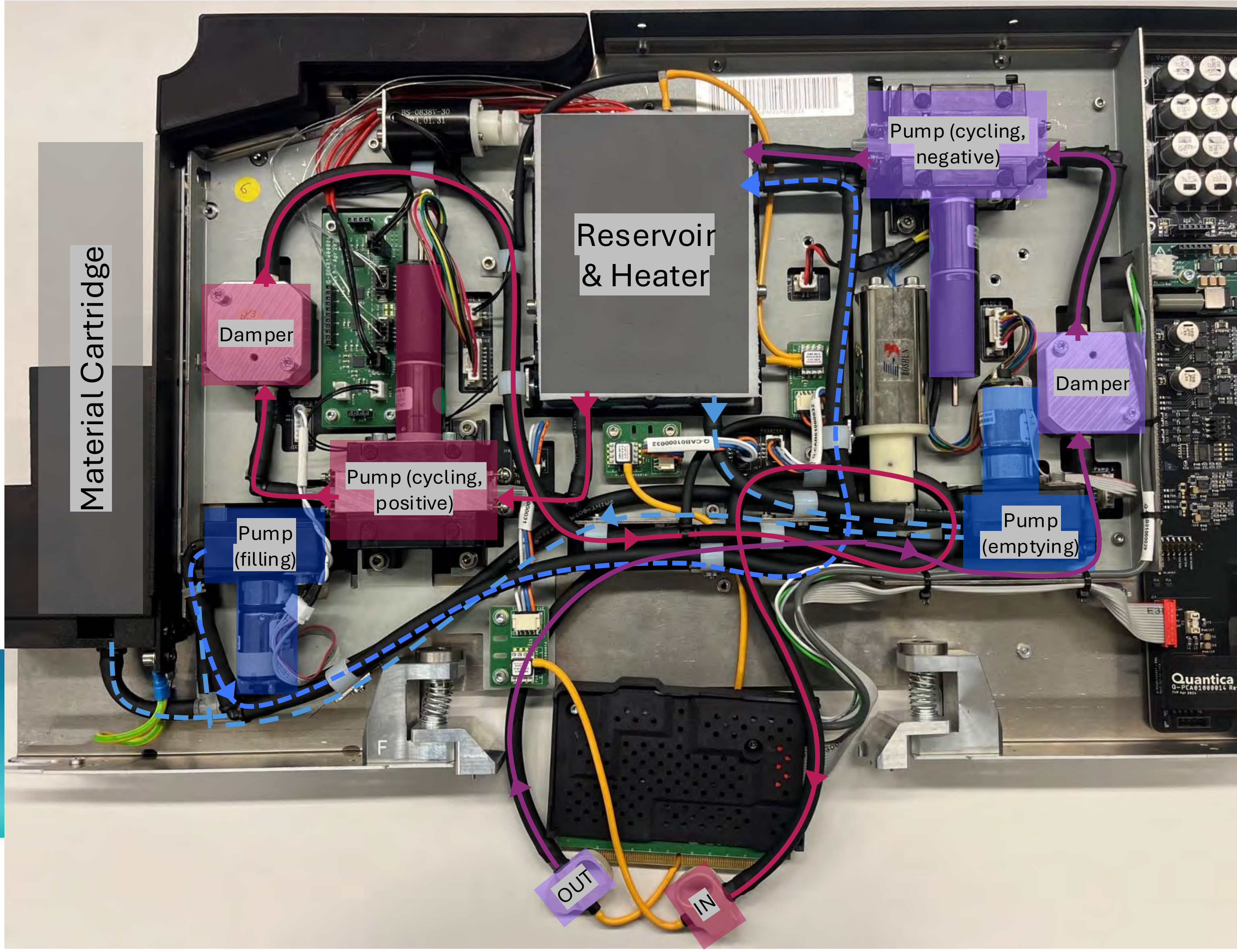
Inkjet Printing

Material supply technology

Quantica JetPack

- Material supply is an important part of inkjet printing

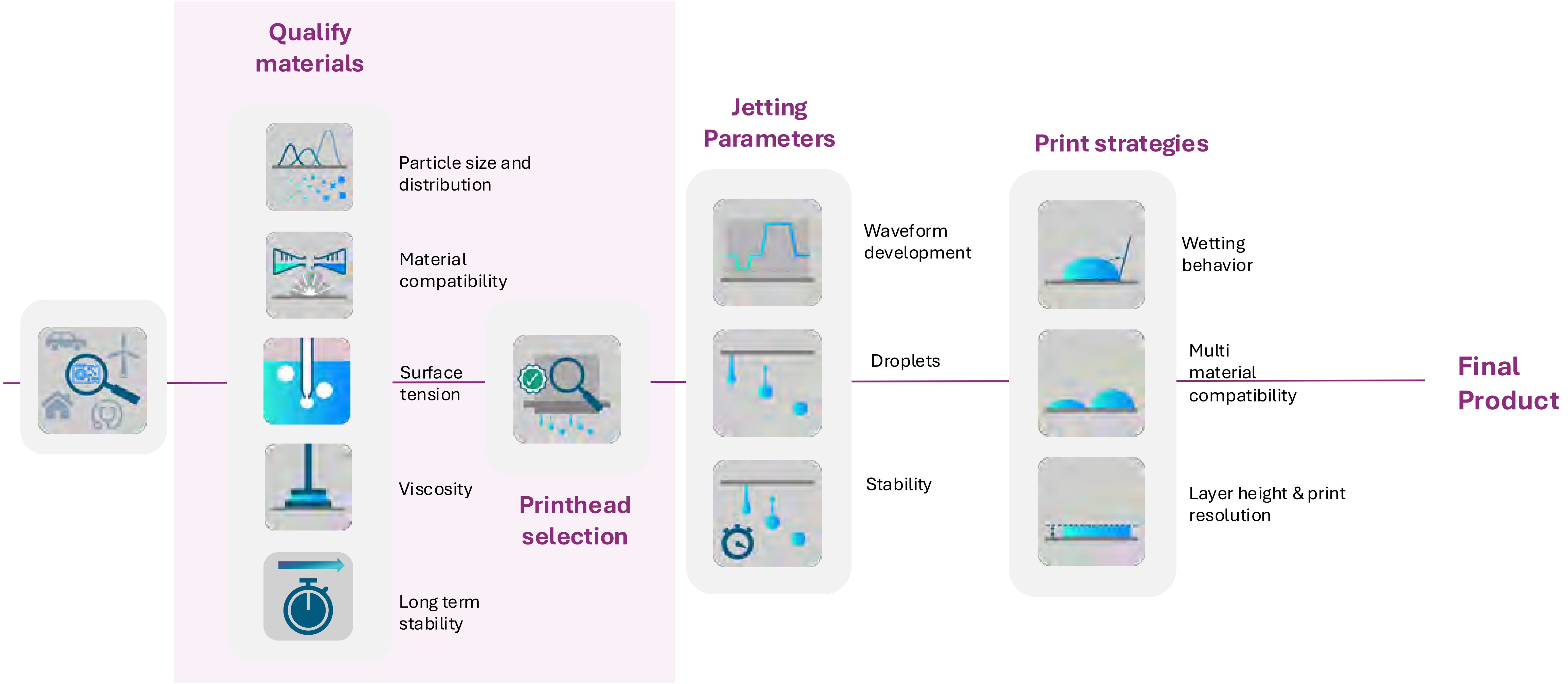
→ ensure a constant flow of material to the printhead



More process parameters need to be monitored than just for jetting through the printhead

Inkjet Printing

Process Development for new materials



Qualifying screen-printing inks for inkjet printing

Material choice

- Selection of two widely used and commercially available screen-printing inks
- Corresponding thinners for the materials were used for cleaning and diluting

	Material 1	Material 2
Color	white	white
Substrates	PVC (hard and foils), acrylate glass, polycarbonate, polyester foils, thick paper, wood	Glass, ceramics, metals, coated substrates, duroplastics
Areas of application	Labels, Stickers, industrial labelling,	Indoor decorations, commercial printing on glass and ceramics
Drying	Physically drying	Chemically curing with hardener
System	Solvent based	Solvent based

Qualifying screen-printing inks for inkjet printing

Choice of experiments

Particle size and distribution

- Real particle size can not be larger than 5 µm
- Measurement of the screen printing inks in their respective thinners

Viscosity

- Viscosity of the materials needs to be adjusted to the jetable window of max. 250 mPa*s

Long term stability

- Stability of the solution at process temperature over time

Material Compatibility

- Ink and thinner need to be compatible with printhead and fluidic supply components

Surface Tension

- Is measured to ensure it is in the processable window of the printhead

Particle size and distribution

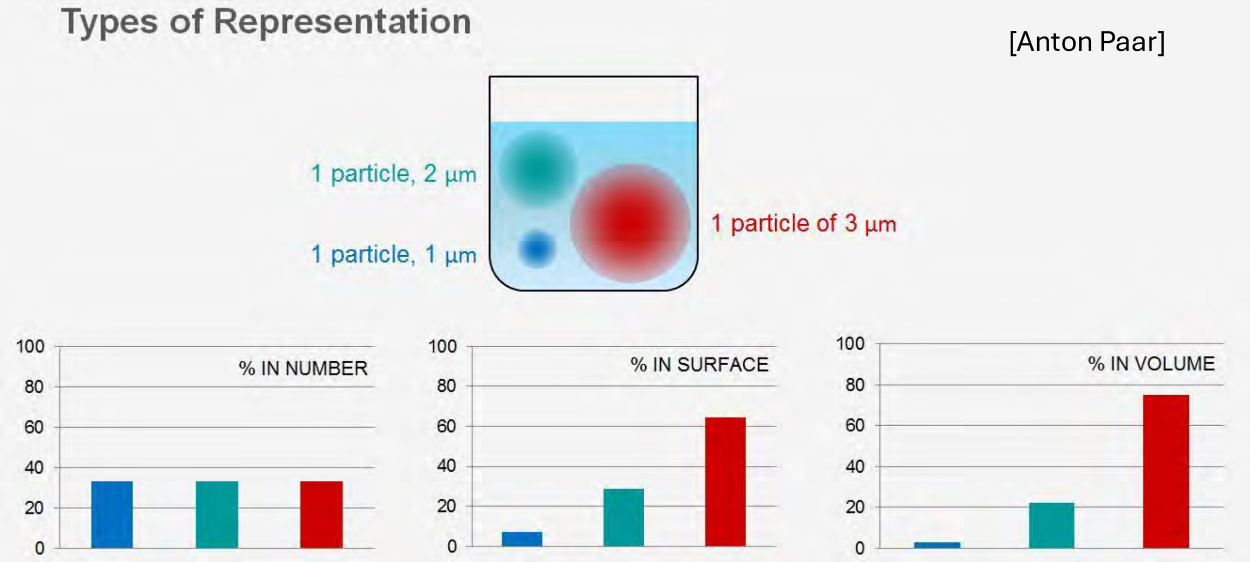
- Tested via **D**ynamic **L**ight **S**cattering (DLS)

Distribution by number

How many particles are present?

Distribution by Intensity

How much light comes from different particles?



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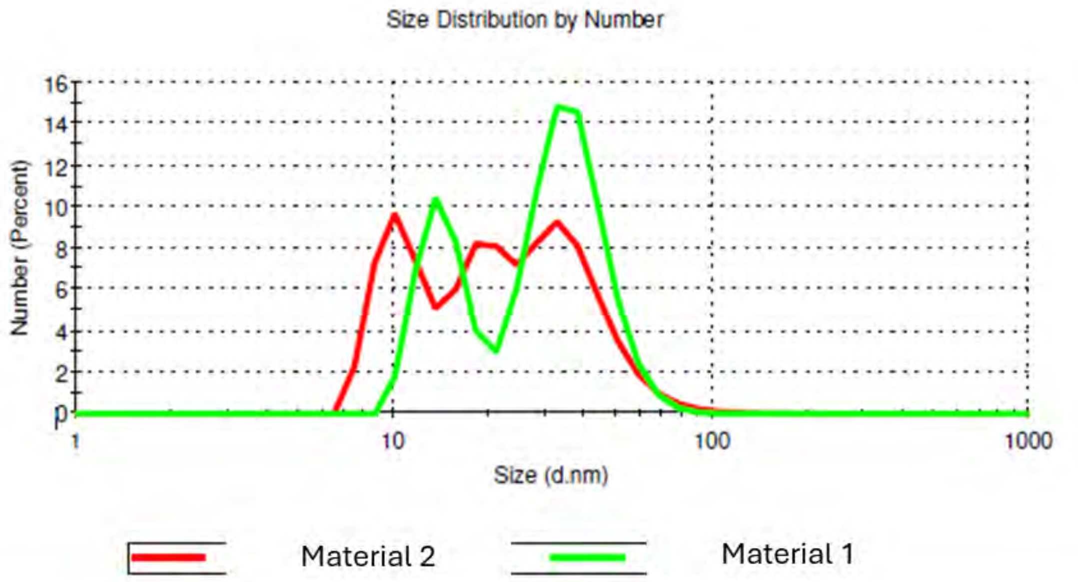

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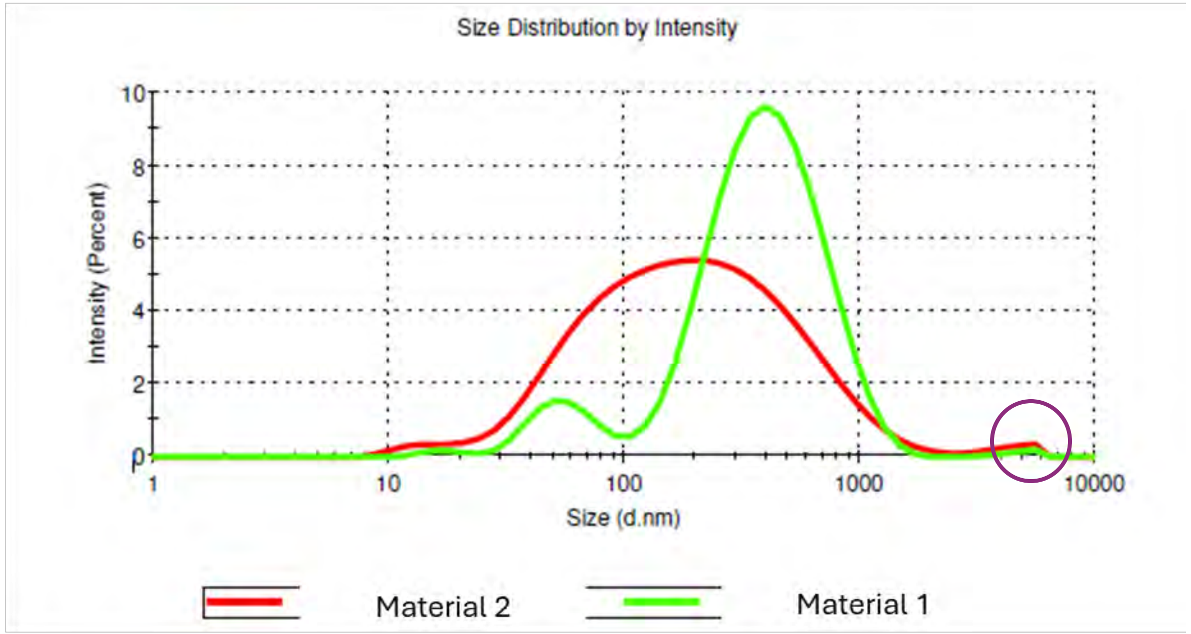


D_v 90 Material 1 = 1,1 µm

D_v 90 Material 2 = 4,5 µm

→ **Both materials have a presumably jettable particle size distribution**

→ **Problems due to agglomerates still possible**

Viscosity

Materials and thinner

Shear dependent viscosity of materials and thinner to get an overview of the material properties

Material 1

- Low shear viscosity of roughly 7000 mPa*s
- Highly shear thinning

→ High shear viscosity of less than 100 mPa*s

Material 2

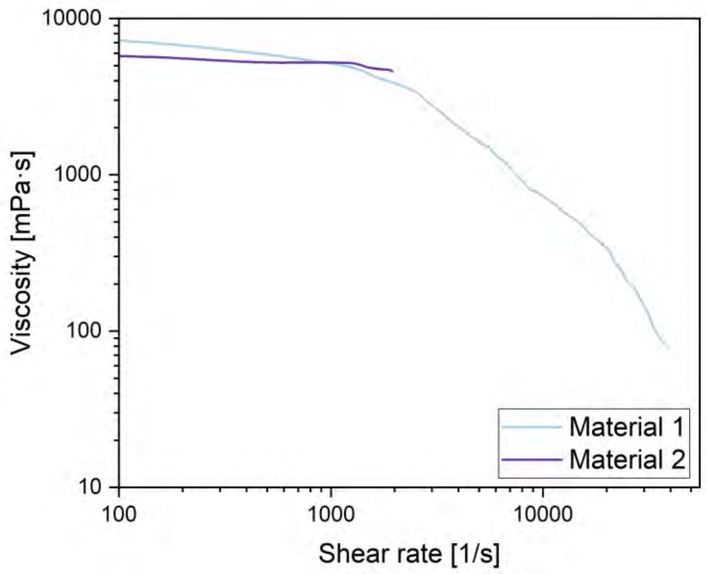
- could only be measured until 2000 1/s
- Viscosity of roughly 5000 mPa*s

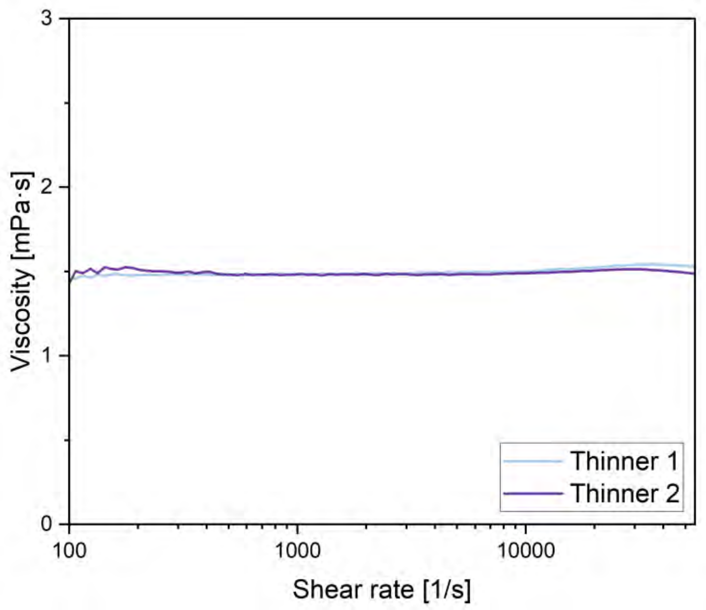
Thinners

- Newtonian behavior
- Viscosity of 1,5 mPa*s

- Shear thinning behavior of Material 1 could be beneficial for jetting
- Even though high shear viscosity is already in printable range material needs to be thinned

→ Material supply has to be taken into account





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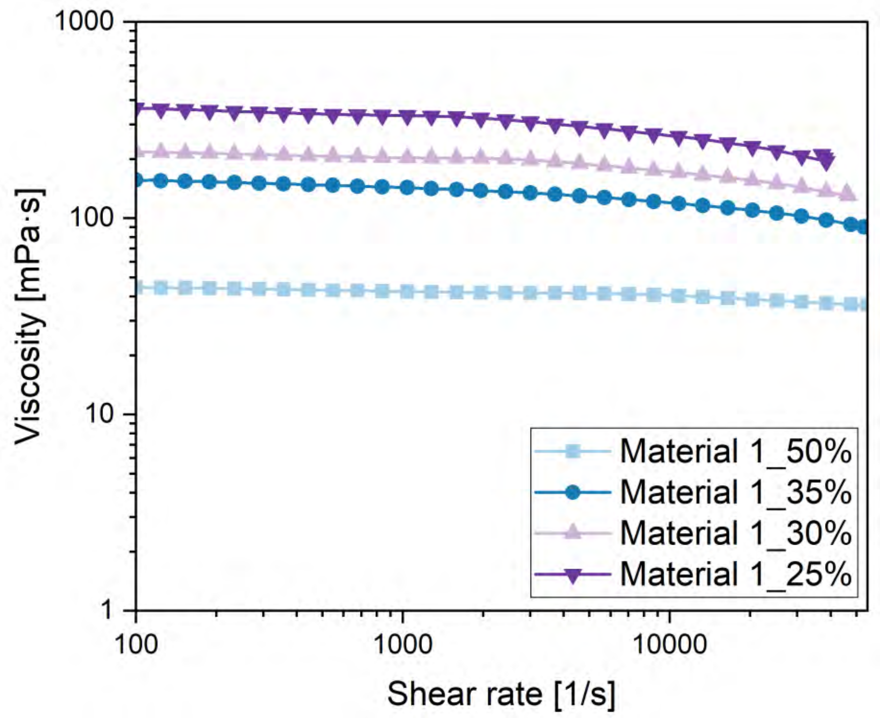
Viscosity

Dilution series – Material 1

Dilute material to fit a process window of around 150 mPa*s

- Material 1 is non-Newtonian
- **Thinner** is Newtonian, which means the amount of thinner not only **governs** the viscosity but also the **rheological behavior** of the mixture
- 35 % of thinner is a possible mixture for further experiments



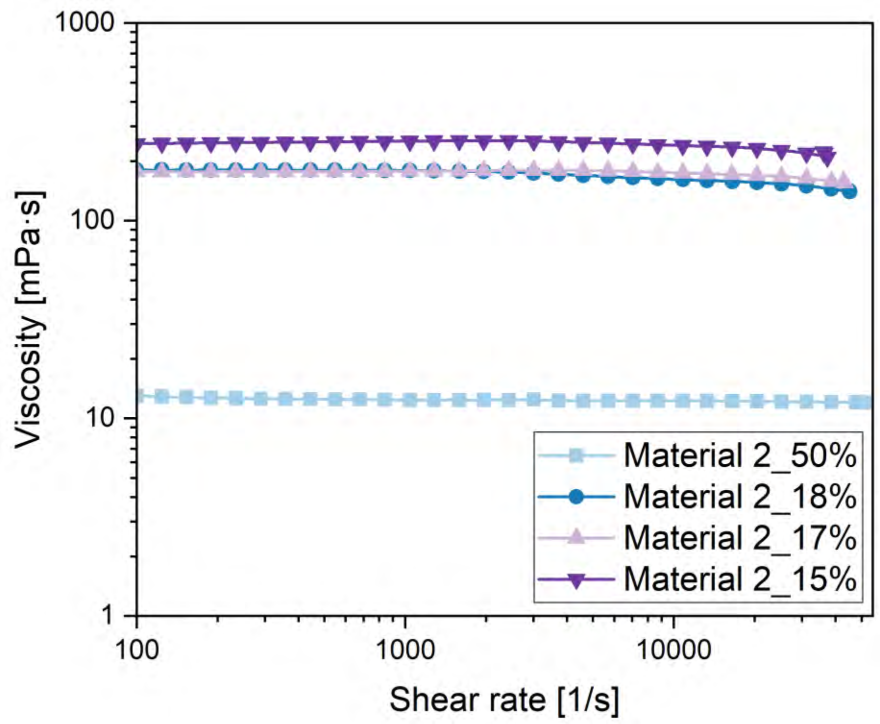
Shear rate sweep with rotational rheometer of the diluted Material 1 at 30 °C

Viscosity

Dilution series – Material 2

Dilute material to fit a process window of around 150 mPa*s

- Material 2 is Newtonian in the dilution of 50 %
- Slight decrease of viscosity at higher shear rates when only 15-18 % of thinner is used
- 18 % could be a possible concertation to move forward



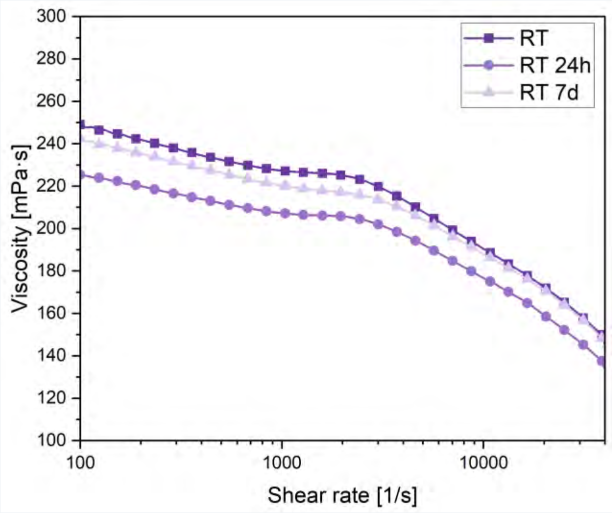
Shear rate sweep with rotational rheometer of the diluted Material 2 at 30 °C

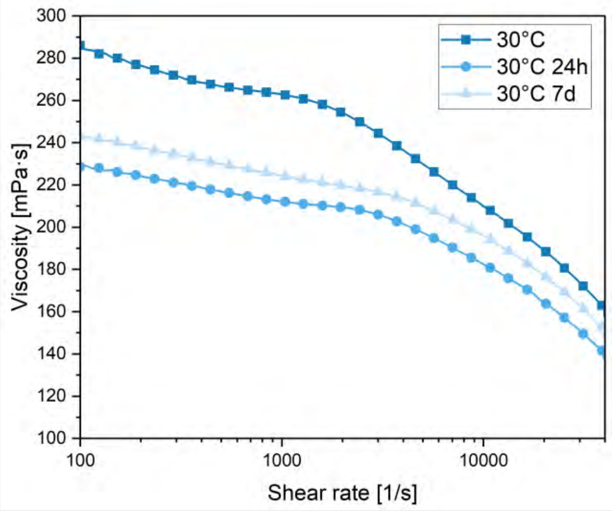
Long term stability

Material 1

Observe stability of a diluted mixture to check for drastic viscosity changes over time that could impede jetting

- **35 % thinner** was used to prepare the mixture of Material 1 for long term stability testing
- Mixture was stored at **room temperature** and at **30 °C**
- Viscosity lower after 24 h
- Slight increase of viscosity between 24 h and 7 days
- Changes are still within the process window





Shear-dependent viscosity of material after **storage at RT and 30 °C** for **24h** and **7 days**

Material Compatibility

Material 1

- **Interactions** between the printhead or MMS and the material can **break down the components**
- Testing of the printhead and material supply system components with Material 1 and the respective thinner
- Monitoring of weight changes and optical differences after 24h and 7 days

- Some weight results hard to interpret since Material 1 was so viscous it could not be cleaned from the parts properly
- Fluoroelastomers were not compatible, especially with the thinner

→ Jetting trials still possible, since issues only in MMS, where parts are easier to replace

	Component	Material 1	Thinner
PH	Polyimide	neutral	good
PH	Epoxy adhesive	good	good
MMS	Polypropylene	good	good
MMS	Fluoroelastomers	neutral	bad
MMS	PP/EPDM	good	good
MMS	Silicone	good	good

Simplified material testing overview for printhead and material supply system components

Surface tension

Material 1

Ensure surface tension is in process window of 30-750 mN/m

- Measured with **bubble tensiometer**
- Bubble lifetime: 2000 ms
- Value for 35 % thinner mixture of material 1: **27,9 mN/m**

- Value is slightly out of range
- **Presumably due to high solvent content**
- Jetting trials still possible, since surface tension is only a small factor
- Adjustment possible, if jetting fails

[SITA Messtechnik GmbH]

Conclusion

Parameters of material 1

Particle size and distribution

- $D_v 90$ = 1,1 µm
- Agglomerates still possible

Viscosity

- Shear thinning
- 35 % thinner yields high shear viscosity of 120 mPa*s

Long term stability

- Viscosity changes over 7 days are not out of the process window

Material Compatibility

- Material 1 and thinner are compatible with the printhead but incompatible with few parts of the MMS

Surface Tension

- Out of process window, presumably due to the high solvent content

Outlook

- Material 1 is fully characterized for following jetting trials
- Determine parameters for material supply system and observe the stability of circulation
- Determine if the material is jettable with the Quantica NovoJet^{TM} printhead
- Set goal parameters for a potential application and refine waveform

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Thank you for your attention!

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Sources

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