Powder focusing for beam induced laser 3D printing

- Powder focusing
  ETHZ IMES J. Dual, PhD Michael Gerlt

- Electrohydrodynamic droplet formation
  ETHZ LTNT D. Poulakakos, PD Patrik Rohner

- Powder drying on flight
  PSI M. Pouchon, PhD Kwanghoon Choi
  Empa S. Vaucher

- Simulation of liquid – particle drying process
  EPFL LFMI F. Gallaire, PhD Shahab Eghbali

- Integration into focused laser 3-D printing system
  Empa LAMP P. Hoffmann, PD B. Lanfant
  Dr. S. Vaucher, Dr. M. Leparoux

Teams complete - project on track
Copper + Silicon as powders selected
Sub-systems ready
Acoustic powder focusing

Experimental Setup

PS Particle - $d = 5 \mu m$

Top: 57 $\mu m \pm 28 \mu m$, Side: 89 $\mu m \pm 25 \mu m.$

Silicon shards - $d = 0.15 \mu m$

Linewidth: 92 $\mu m \pm 17 \mu m.$

Michael Gerlt & Jürg Dual
Electrohydrodynamic printing

- **Micro- / nanodripping mode**
  - Nanoparticles used: CdSe quantum dots, $d = 8$ nm
  - Nozzles range from 800 nm to ~ 40 μm
    - Picture above: 4 μm
    - Picture on the right: 800 nm
  - Dripping frequencies usually below 1 kHz

- **Cone jetting mode**
  - Nanoparticles used: Gold, 5 nm
  - Nozzle diameter: 30 μm
  - Stage translation speed: 0.3 mm/s
  - Depending on the solvent (e.g. for water), the printing resolution is now limited by the solvent evaporation
High-throughput droplet generation and microwave resonator

Experimental setup

**High-throughput droplet generation**

- **Material**: Water (20°C)
- **Nozzle dia.**: 60 µm
- **Flow rate**: 0.5 ml/min
- **Frequency**: 15 kHz
- **Droplet size**: 3.5%

High-throughput droplet generation (15kHz) with simulation are validated.

**Loop-gap resonator microwave drying**

Strong and uniform E-field of resonator is designed.

Kwanghoon Choi, Manuel Pouchon
Problematic:
- What is the effect of solid particles on laminar jet destabilization?

Methodology: Numerical Simulation

Observations
- Multistage non-linear modification of the pinch-off dynamics

Outlook: How to control the output of particulate jet destabilization?

Break up time: \( t_p = 59\, ms \quad t_p = 55\, ms \quad t_p = 78\, ms \)

\[
Oh = \frac{\mu}{\sqrt{\rho \gamma R}} = 10 \\
R_p = 0.6 \\
\rho_s / \rho = 10
\]
SFA Project: Powder focusing for beam induced laser 3D printing

WP5 - Prototype LMD reactor modification

Axicone optical system: Ø: 20 µm, coaxial powder injection

Thank you

Arnaud Mader, Briac Lanfant, M. Leparoux, P. Hoffmann