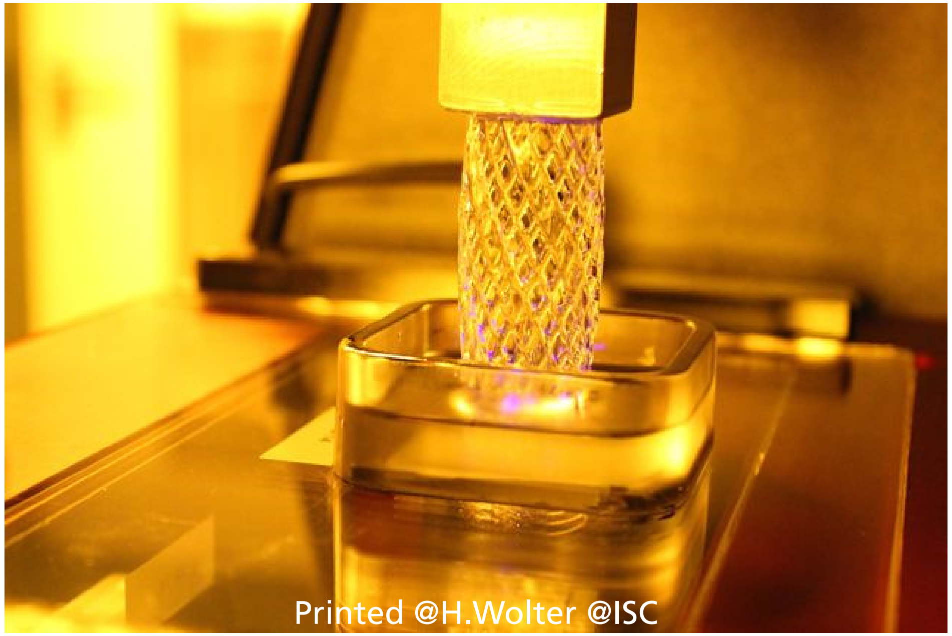
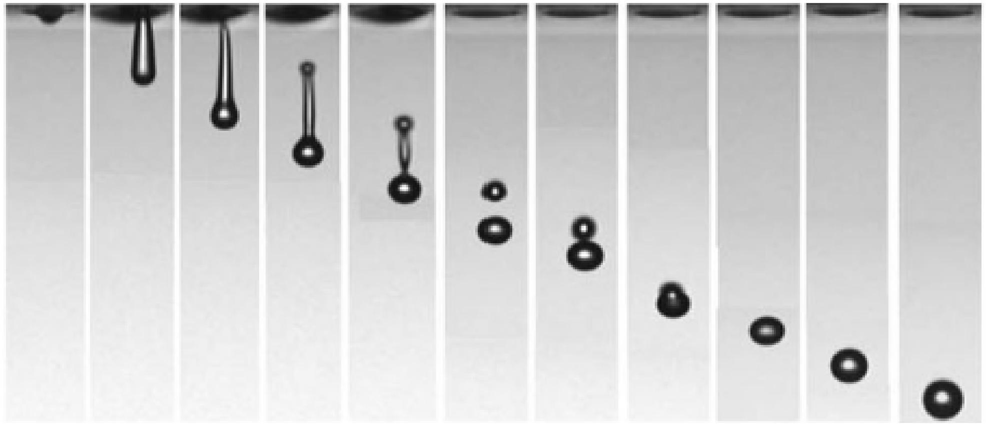
New materials for additive manufacturing of optical components - From DLP to Inkjet





A.Matavz, B. Malic, *J. Sol-Gel Sci. Techn.*, **2018**, 87

Matthias Klein – 17.09.2019

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WIR STIFTEN ZUKUNFT

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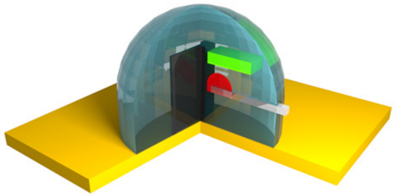
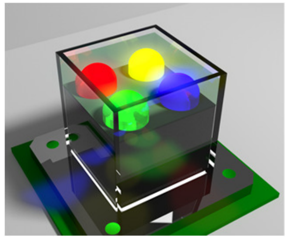
Overview

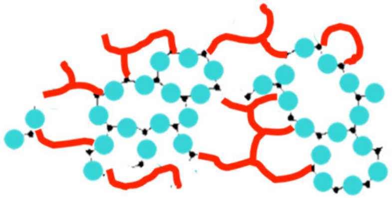
Motivation



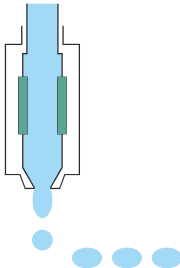
DLP / Sensor Chip



Material



Inkjet



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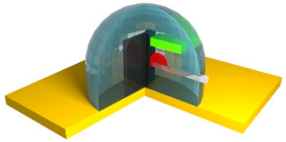
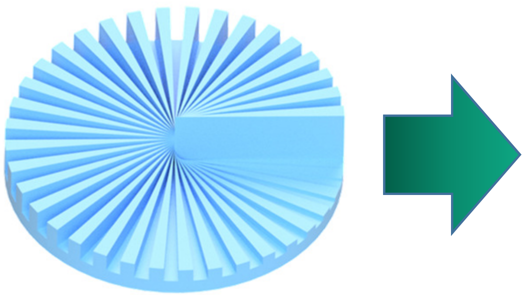
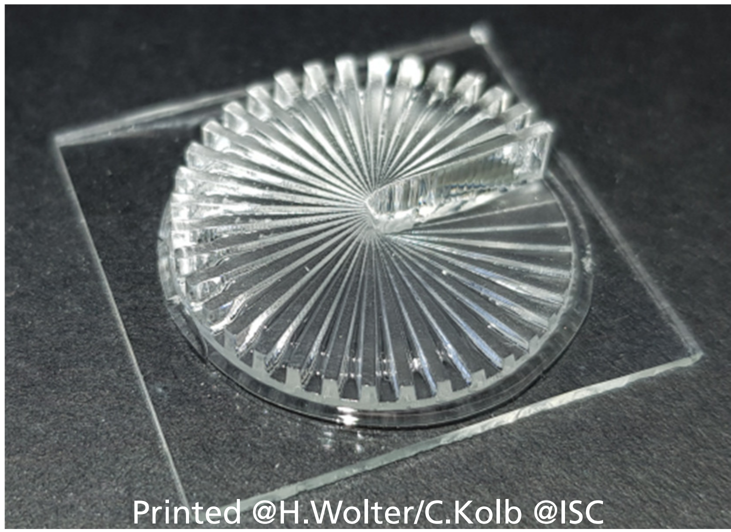
Additive manufacturing – but why?



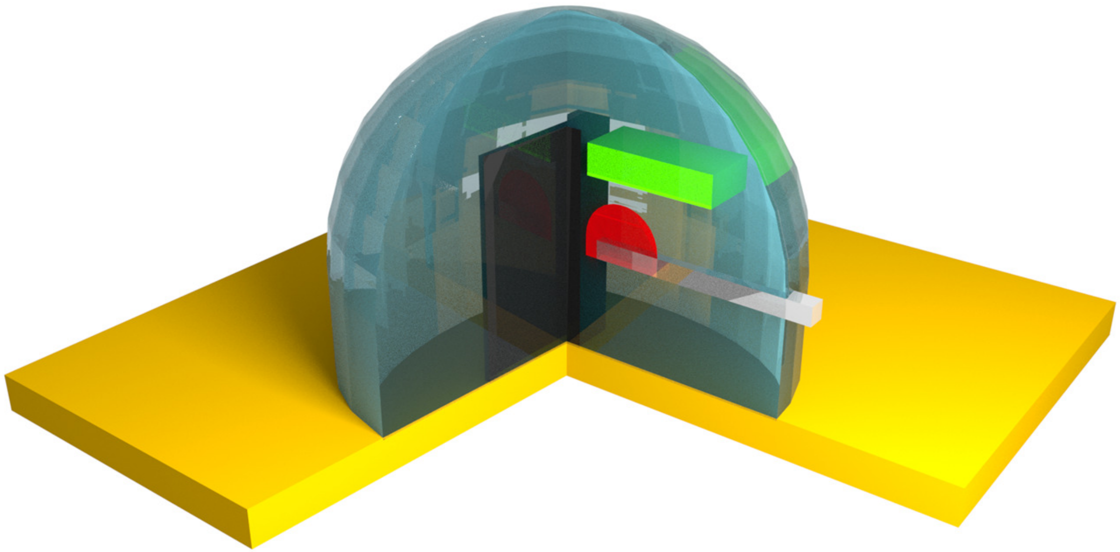
- Injection molding
  - Time-consuming
  - Expensive
- Additive manufacturing
  - Complex structures
  - Rapid prototyping
  - Adaptable

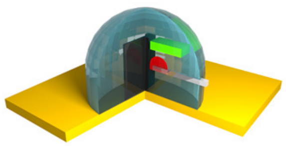




Additive manufacturing – but why?

- Directly integrating functionalities





- Substrate
- Transparent Material
- Conductive tracks
- LED
- Baffle
- Other functionalities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©Daniel Korpai@unsplash
©Przemyslaw Marczynski@unsplash
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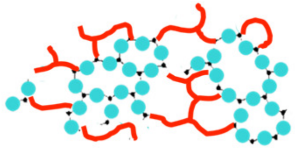
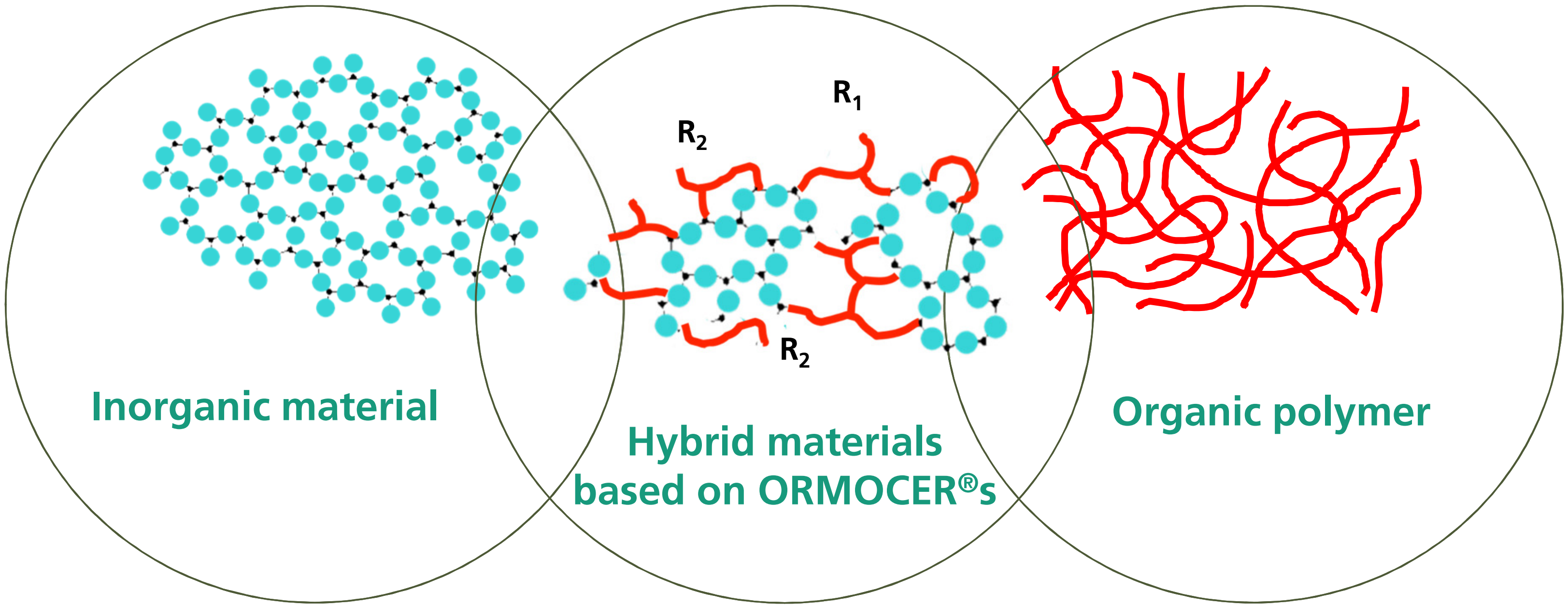
Material requirements



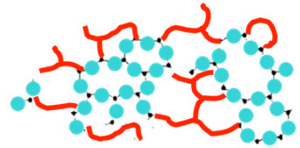
- 3D-printable (DLP – viscosity, solvent free, etc.)
- Stable in shape/dimensions
- Highly transparent
- No yellowing
- Stable vs. environmental influences
- Bioinert/non-toxic

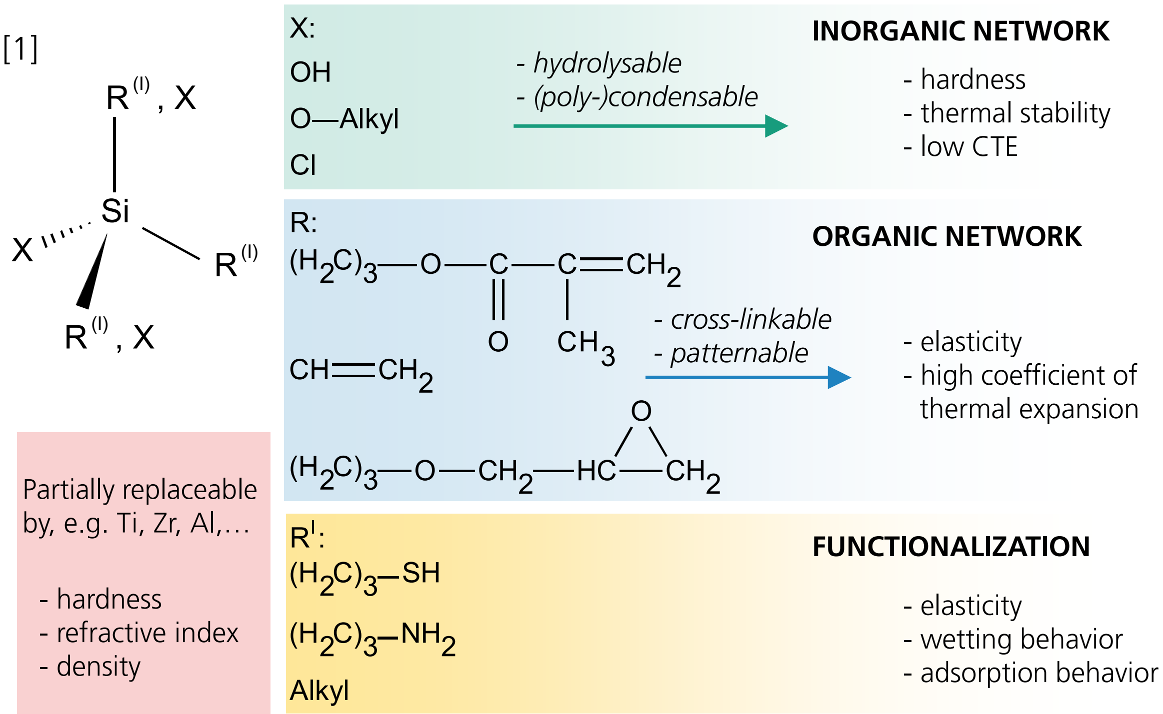
Introduction to ORMOCER® material

ORMOCER®
creative use of adjustable material properties generates new functions



Introduction to ORMOCER® material

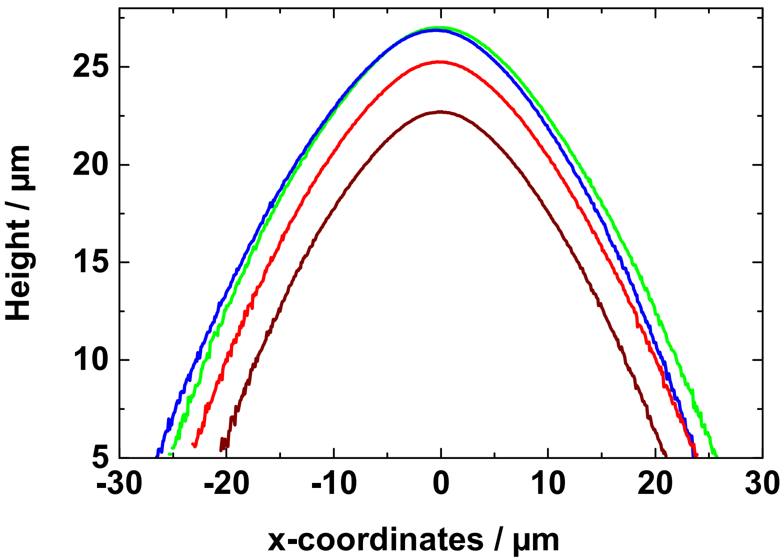


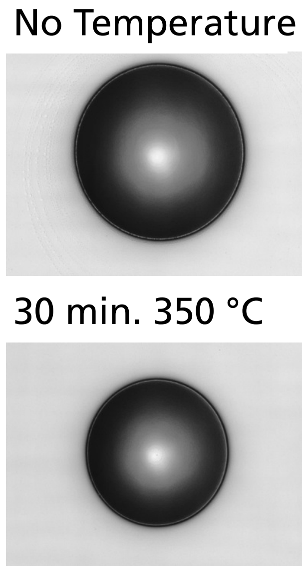


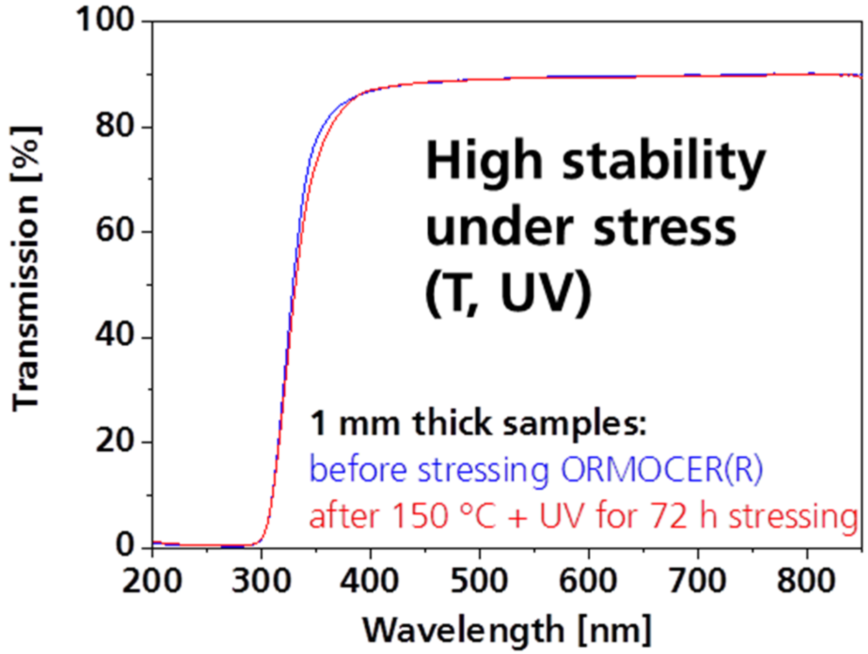
- **Photo cross-linkable polymer**
- **Adjustable optical properties:**
  n = 1.45 – 1.60
- **Low absorption at defined wavelengths**
- **Biocompatibility and degradability for biomedical applications**
- **Formulation with nanoparticles possible**

[1] R. Houbertz et al., "Two-Photon Polymerization of Inorganic-Organic Hybrid Polymers as Scalable Technology Using Ultra-Short Laser Pulses", in Coherence and Ultrashort Pulse Laser Emission, F. J. Duarte (Ed.), (InTech, 2010)

Introduction to ORMOCER® material





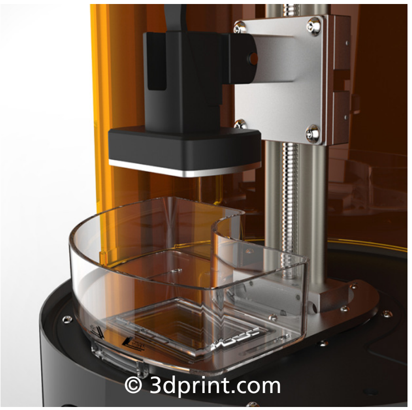


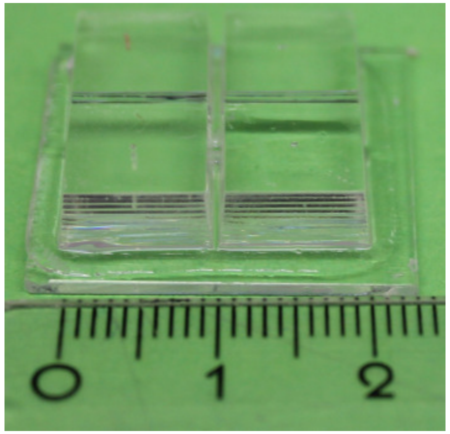
High thermal and UV stability

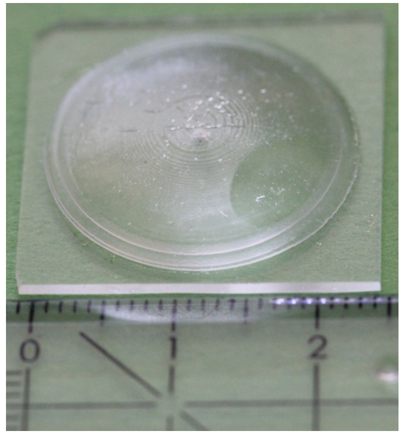
3D-printing – DLP-SLA

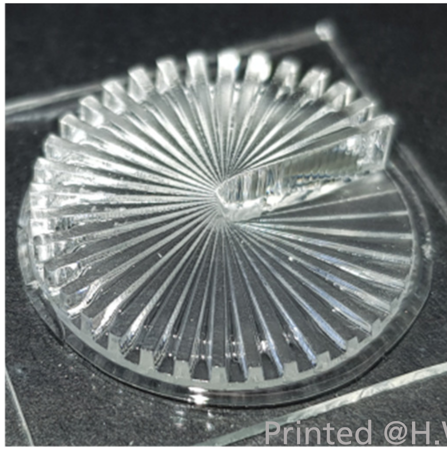
Rapidshape @ Fraunhofer ISC

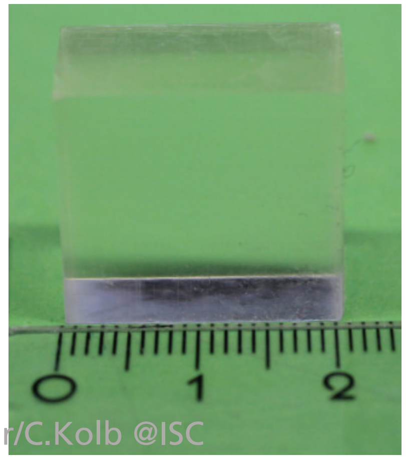
Autodesk Ember @ HS Aalen





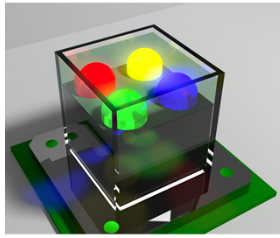




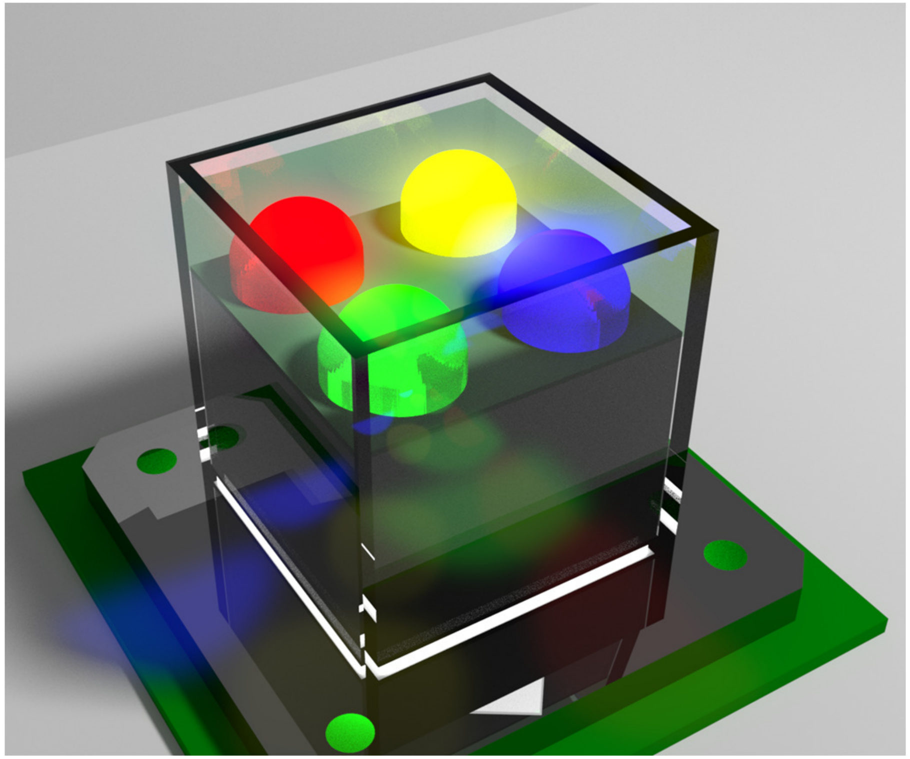


Printed @H.Wolter/C.Kolb @ISC

Sensor-Chip with quantum dots



- QDs as emitters
- ORMOCER® frame
- UV LED as light source
- Combined with spectrometer
- Biomedical application
- Simultaneous printing



» Adaptable and easy to produce sensor chip

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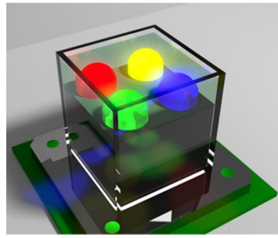
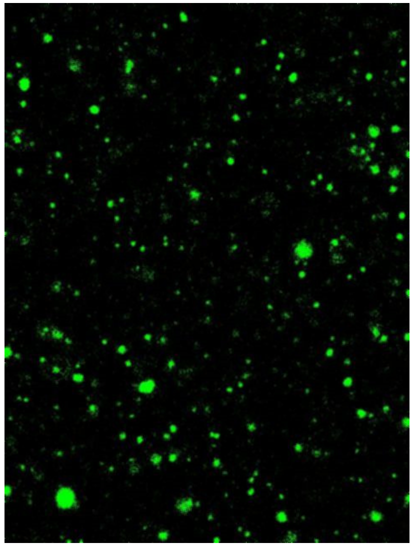
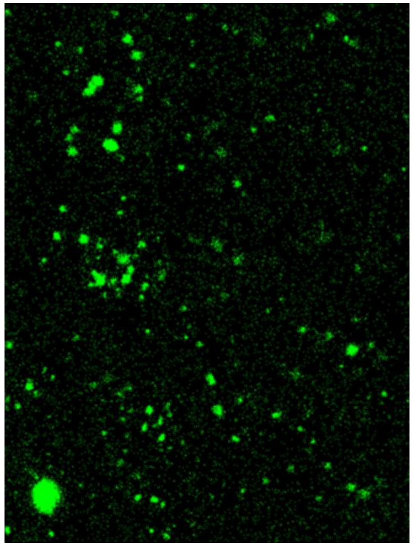


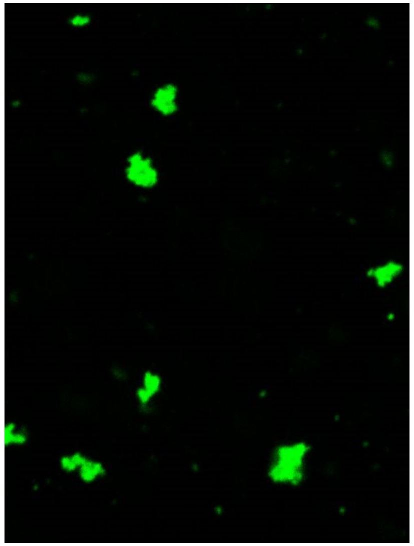
Designing resin-NP-composites



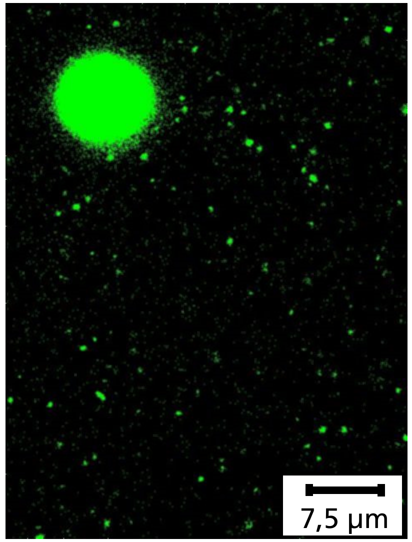
1:1



2:1



1:2



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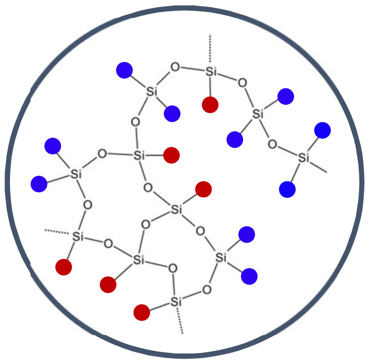
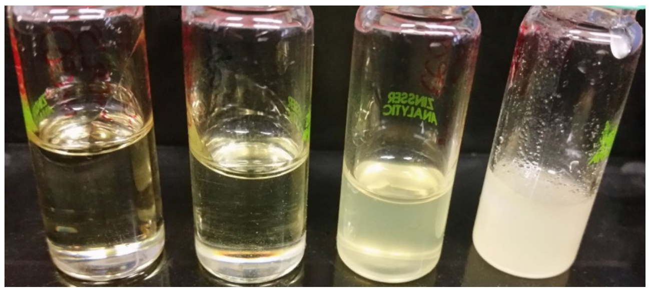
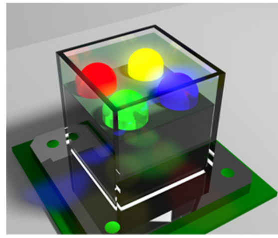




Variating functional groups
Methacrylate-groups
(Di)Phenyl-groups

Resin-Quantum dot-composite



ORMOCER®-resin; 0.03 wt.% QDs

cured

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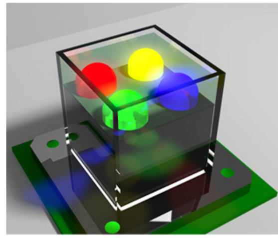
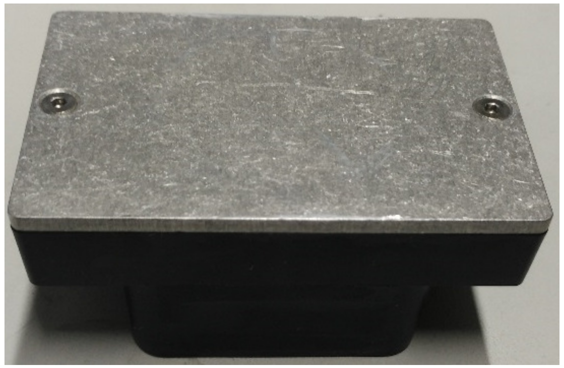
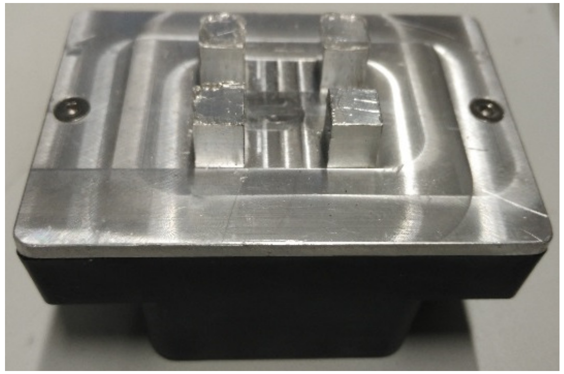
DLP Setup



Normal setup



Modified setup



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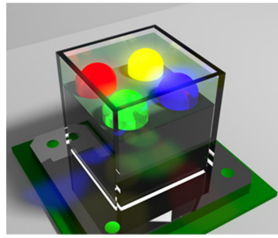
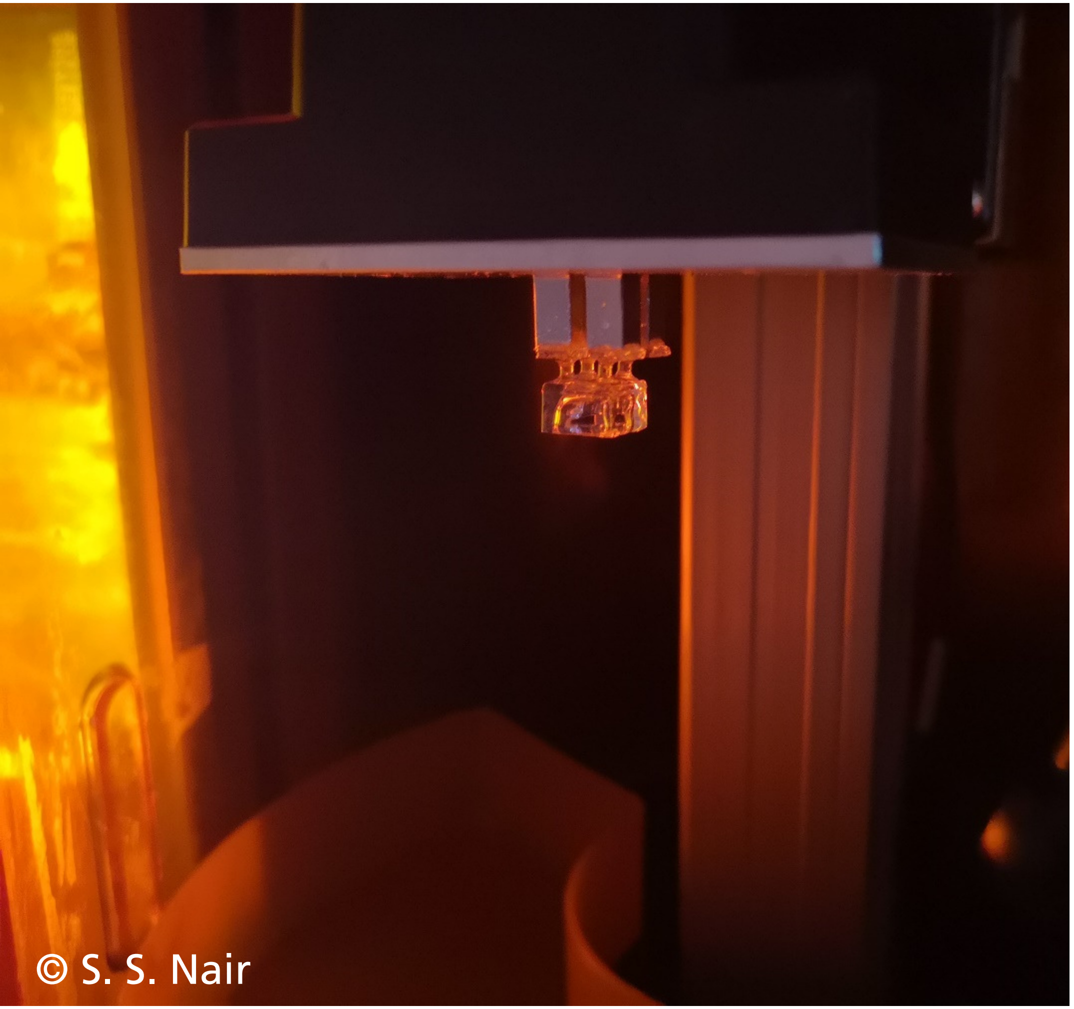
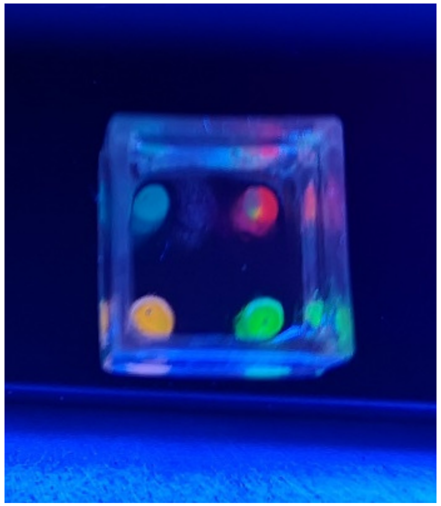
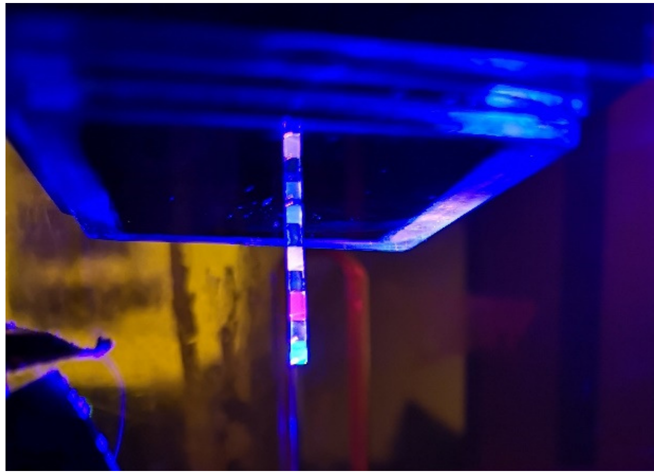
Printing 4 materials simultaneously









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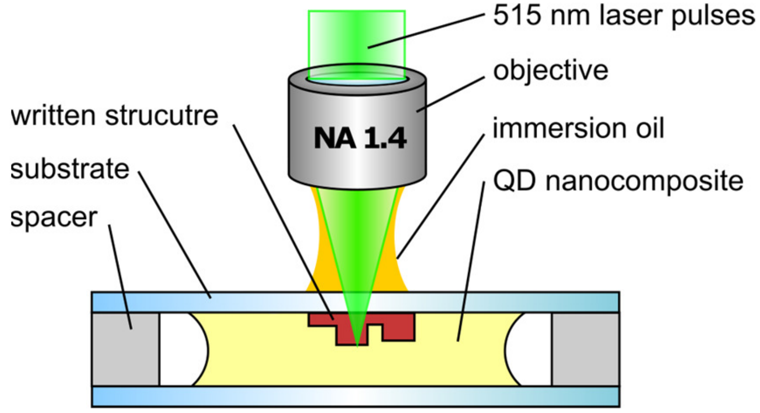
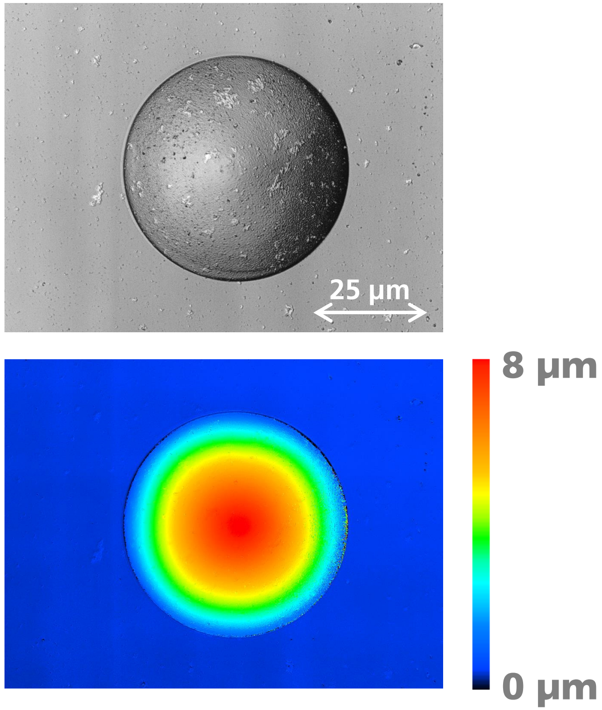
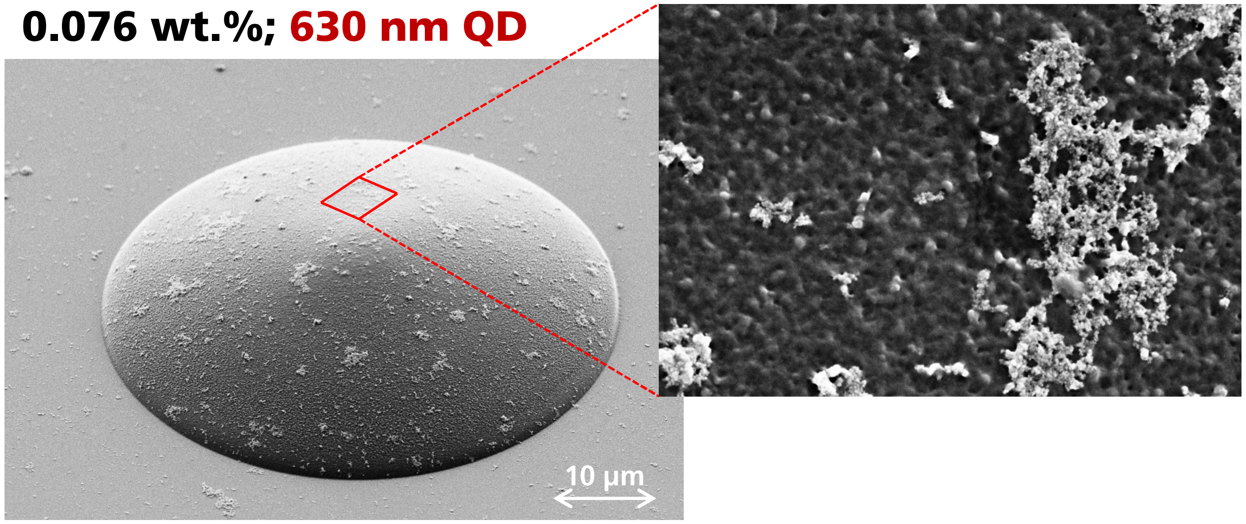
2PP in QD nanocomposite



- Recent results with high-NA 2PP in nanocomposite
- Fabrication of a microlens (Ø = 50 µm; ROC = 60 µm)



0.076 wt.%; 630 nm QD



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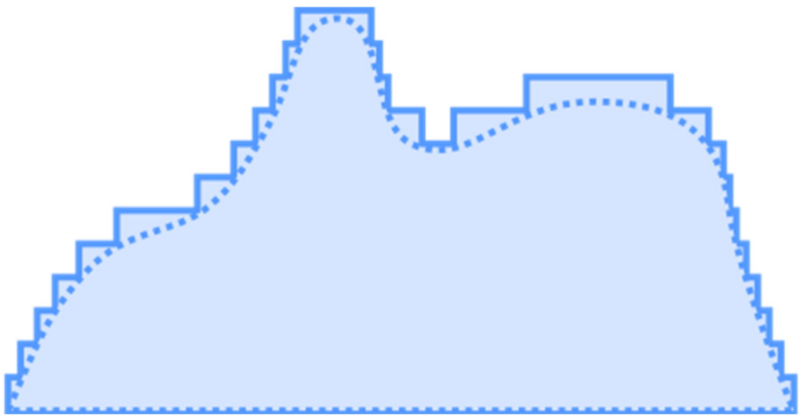
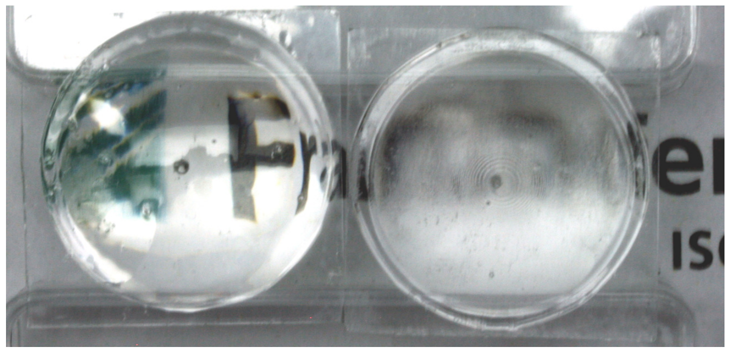
Why do we need Inkjet?

- Digital artifacts
  - Layer by layer
  - DLP mirrors
    - Haze



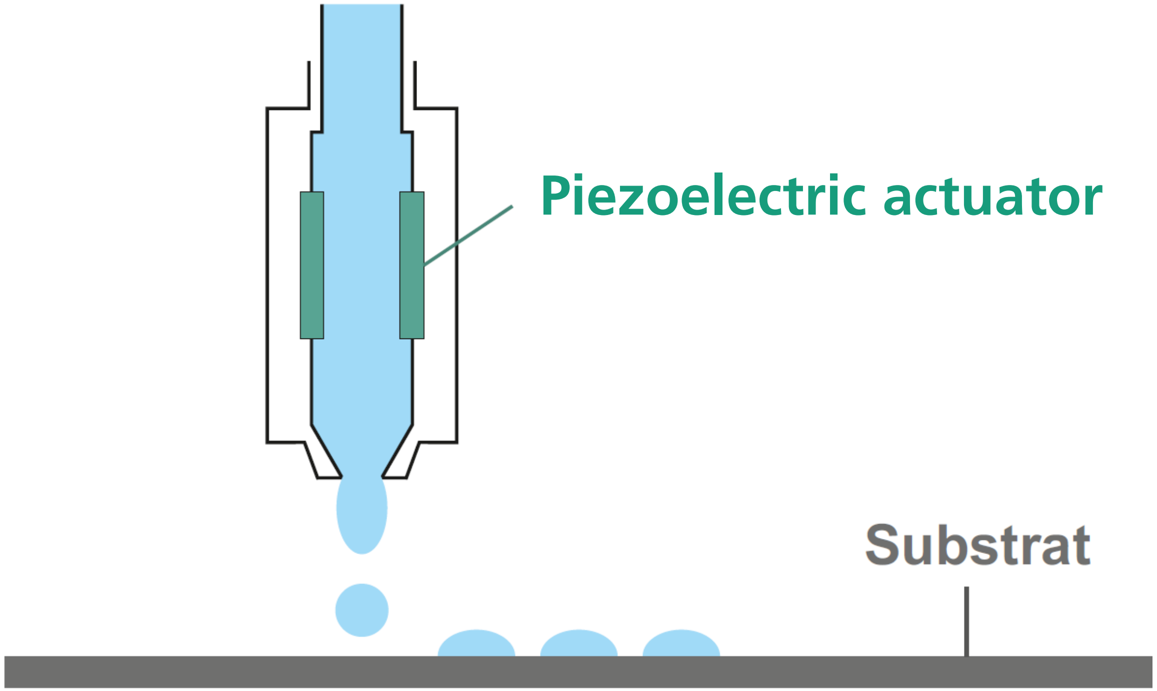


DLP printed lenses with and without extra smoothing step

Inkjet

Inkjet - principle

- Inkjet scheme



Adapted from: *A. Shama, Study of Microfluidic Mixing and Droplet Generation for 3D Printing of Nuclear Fuels,* **2017**, *École Polytechnique Fédérale De Lausanne.*

- Continuous inkjet printing
- Drop-on-demand inkjet printing
- Dropsize between 10-150 µm
- Nozzle diameter ca. 10-20 µm

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KM3

Inkjet

- **Requirements**
  - **Viscosity (η): 10-15 mPas**
    - **(Water: 1 mPas; n-Pentane: 0.2 mPas; Honey:10000 mPas)**
  - **Surface tension (γ)**
  - **Density (ρ)**

Challenge: Viscosity

KM3 Bisherige Harze: hunderte bis

Klein, Matthias; 12.12.2018

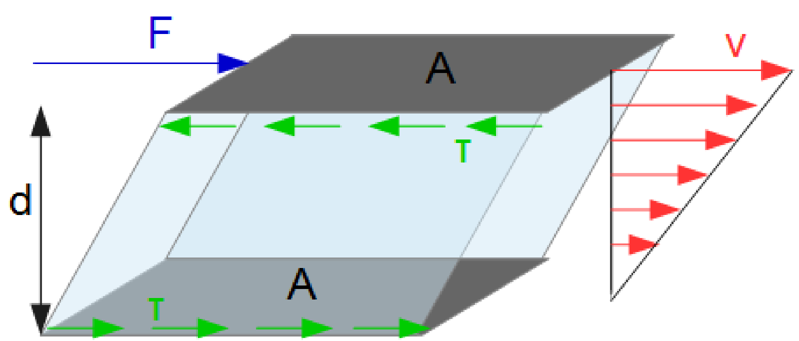
Inkjet

- Viscosity adapting by:
  - Reactive diluents
    - Properties of resin are strongly changed
  - Solvents
    - Low mass percentage of resin:
      - Low film thickness
      - Coffee stains
      - Problems with printing consistency
      - Limited heating (evaporation)

Pure resin

Viscosity

- Viscosity depends on
  - Temperature
  - Structure of molecules



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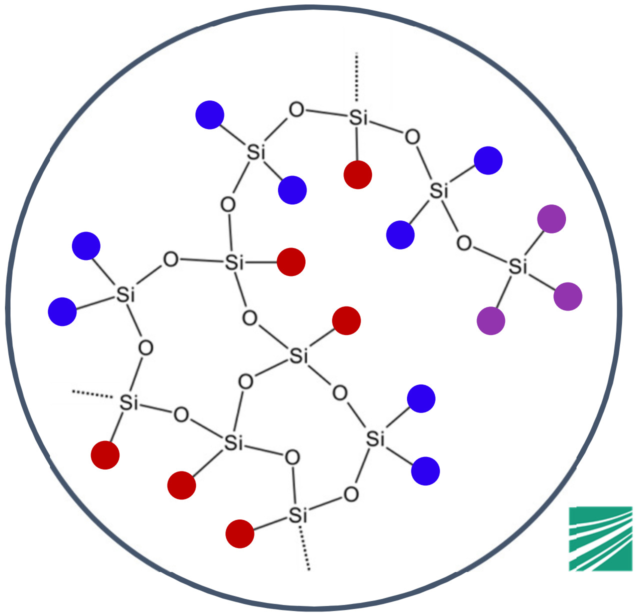
- Manipulation of viscosity of ORMOCER®s
  - Polarities
  - Cross-linking
  - Chain length



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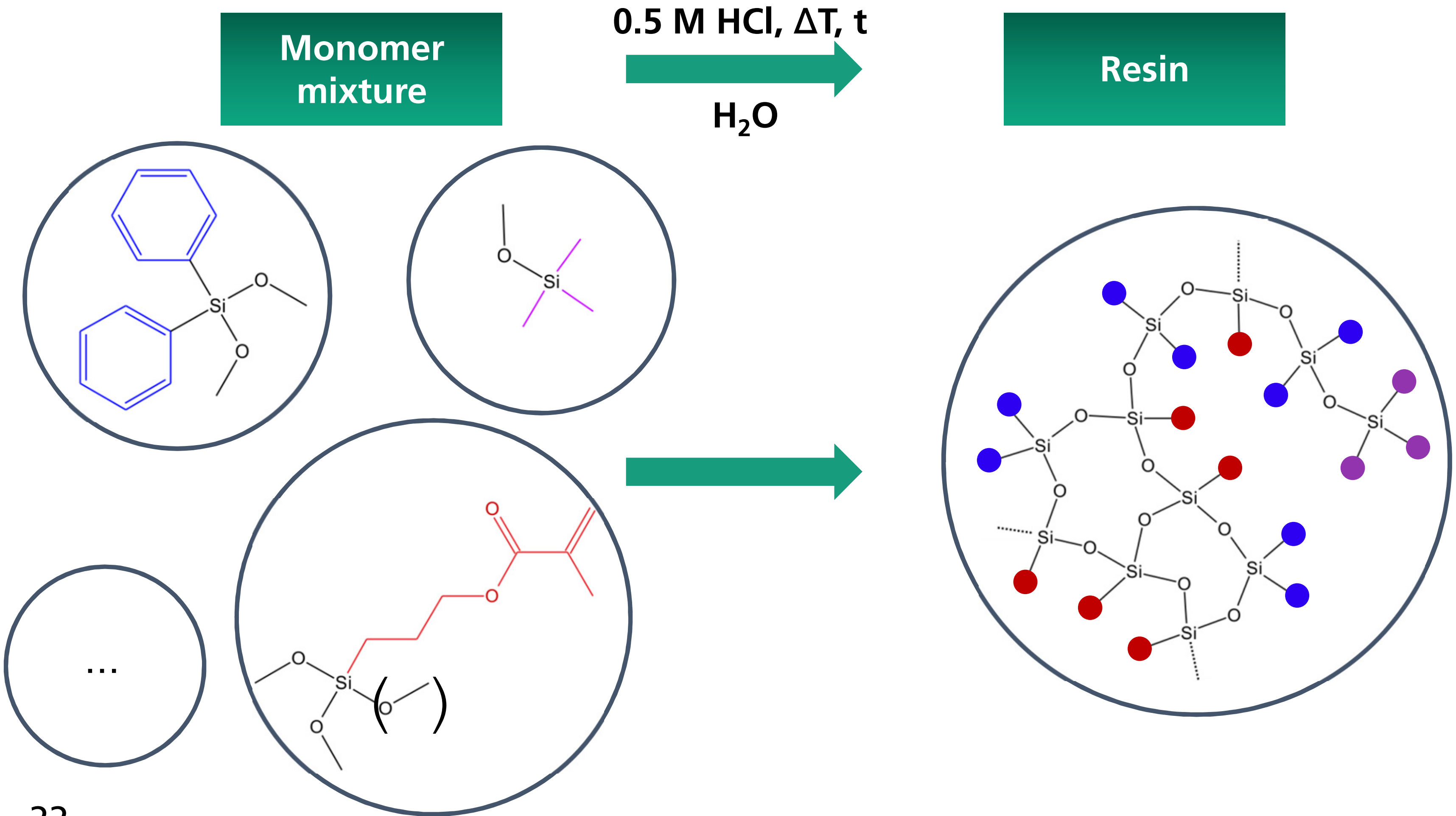
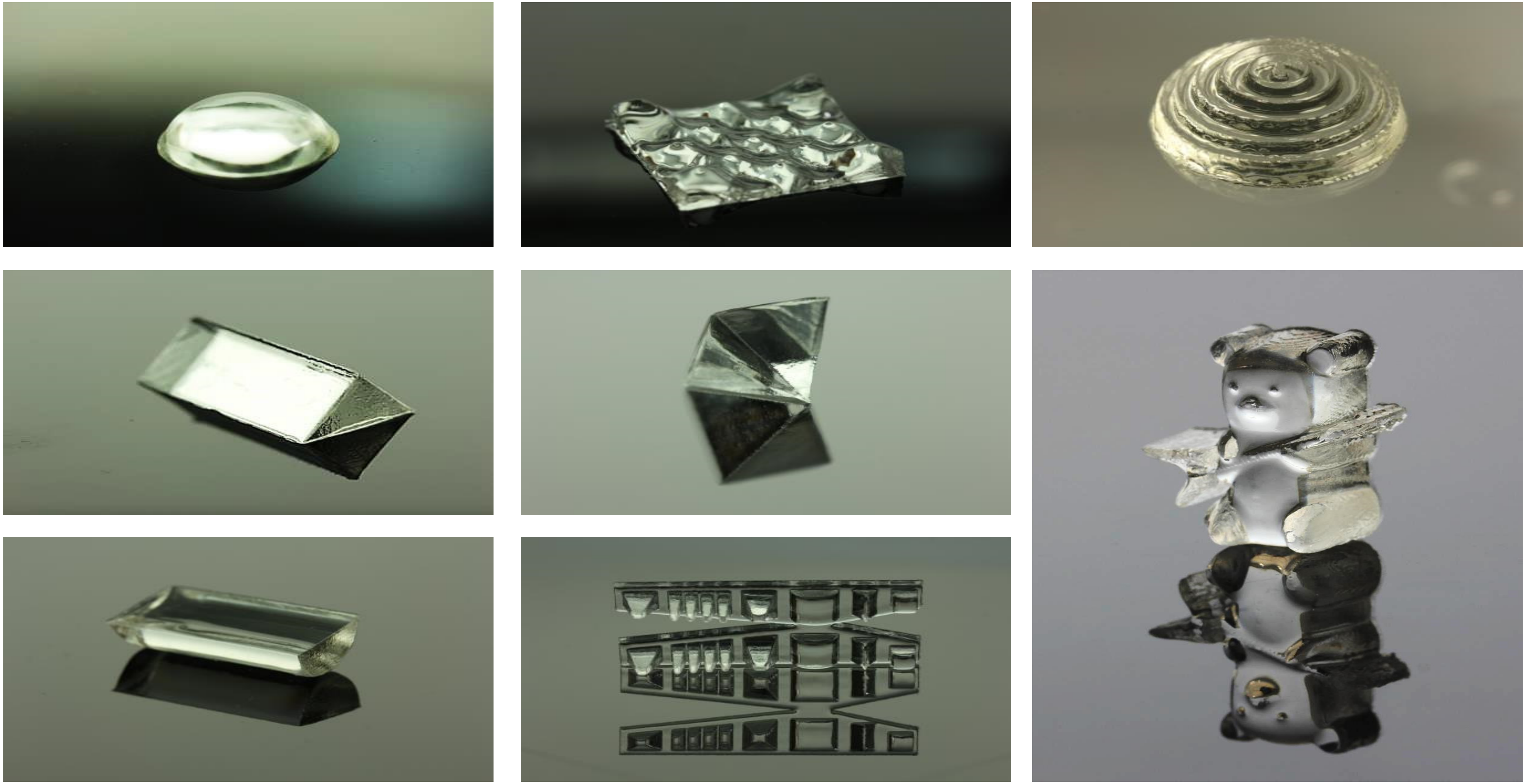
Synthesis



- Variation of Monomers and reaction conditions:
  - Viscosities down to 50 mPas



Exemplery material

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THANK YOU FOR YOUR ATTENTION!

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- Fraunhofer IOF (Falk Kemper, Erik Beckert)
- Hochschule Aalen (Sangeetha Suresh Nair, Prof. Andreas Heinrich)

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