Polymers with Customizable Optical and Rheological Properties based on an Epoxy Acrylate based Host-Guest System

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PlanOS
SFB/TRR 123
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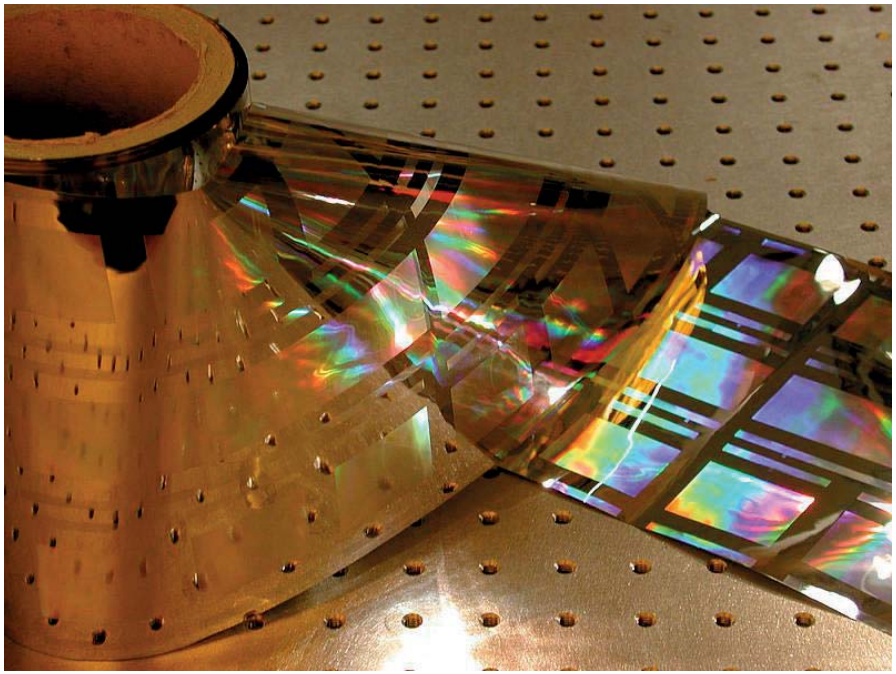
IMTEK - Institut für Mikrosystemtechnik

Planar Optronic Systems

Collaborative Research Center

- Polymer-based sensor network
- Large-area foils
- No electronic components
- Measurement of
  - Temperature
  - Strain
- Sub-projects
  - Suitable materials
  - Construction of fiber optics
  - Light sources
  - Spectrometers / detectors



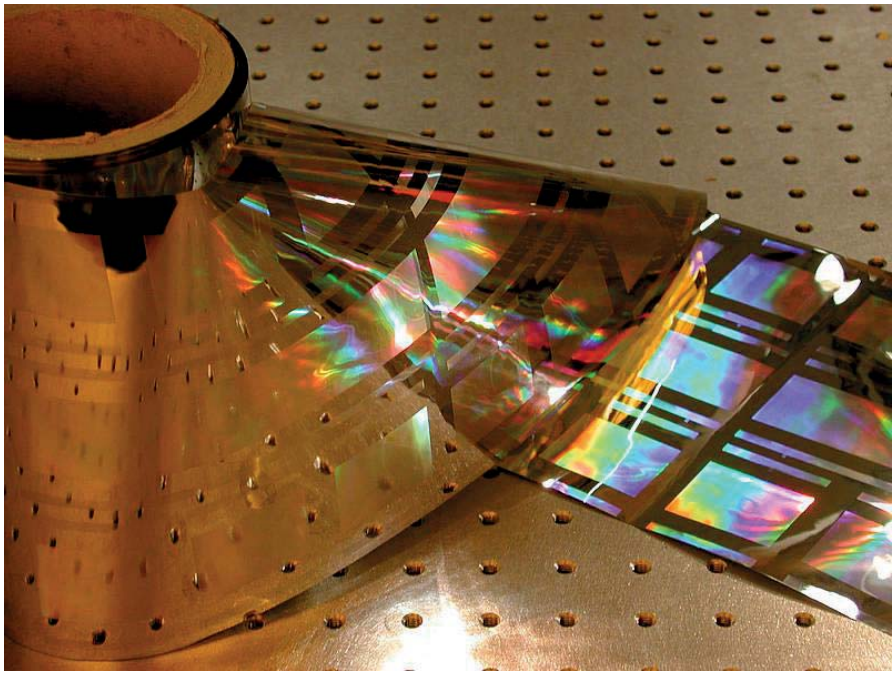
polymer foil

[http://www.planos.uni-hannover.de]

Planar Optronic Systems

Why polymers?

- Modifiable to application
- Good processability
  - Hot embossing
  - NIL
  - Inkjet-printing
  - …
- Large-scale systems possible
- Thin layers = economic



polymer foil

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Tailored polymers

- Adjusting viscosity
- Polymerization by UV-light
- Adjusting refractive indices
- Low optical damping
- Continuous operating temperature

Tailoring viscosity

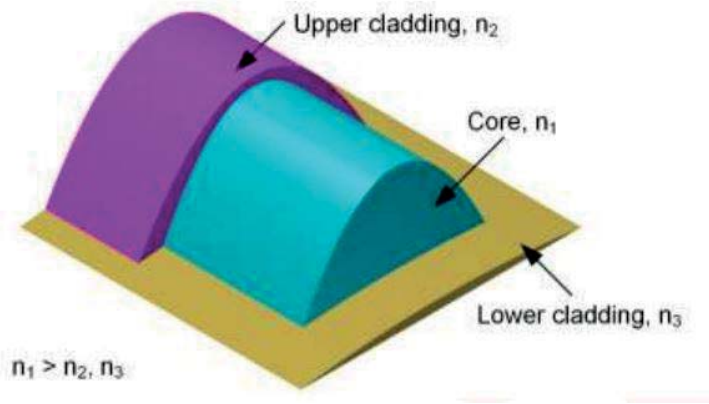
- Comonomer content
- Different shaping / molding processes
  - Inkjet printing
    ≈ 10 mPa·s (@ 70 °C)
  - Offset printing
    ≈ 200 mPa·s (@ RT)
  - Spin coating
    ≈ 100 mPa·s – 1000 mPa·s (@ RT)

Dimatix DMP 2831 [www.electronic-data.com]

Heidelberg Speedmaster SM 52 [www.heidelberg.com]

Adjustment of refractive indices

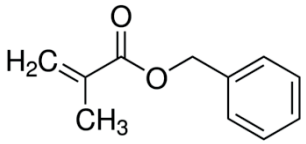
- Comonomer / dopant
- Waveguides
  - Core
  - Cladding
- Coupling structures



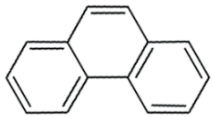
Computed 3D model of printed waveguide (Wolfer et al, Procedia Technology, 2013)

Materials

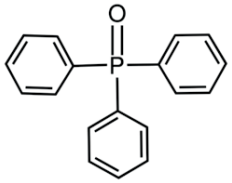
- Main monomer
  - Epoxy Methacrylate 97-053 (RAHN)
- Comonomer
  - Benzyl methacrylate



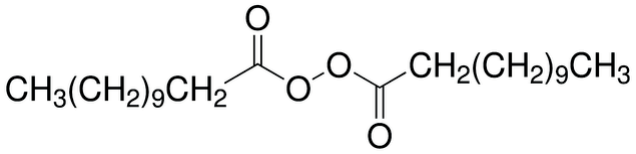
- Dopant
  - Phenanthrene



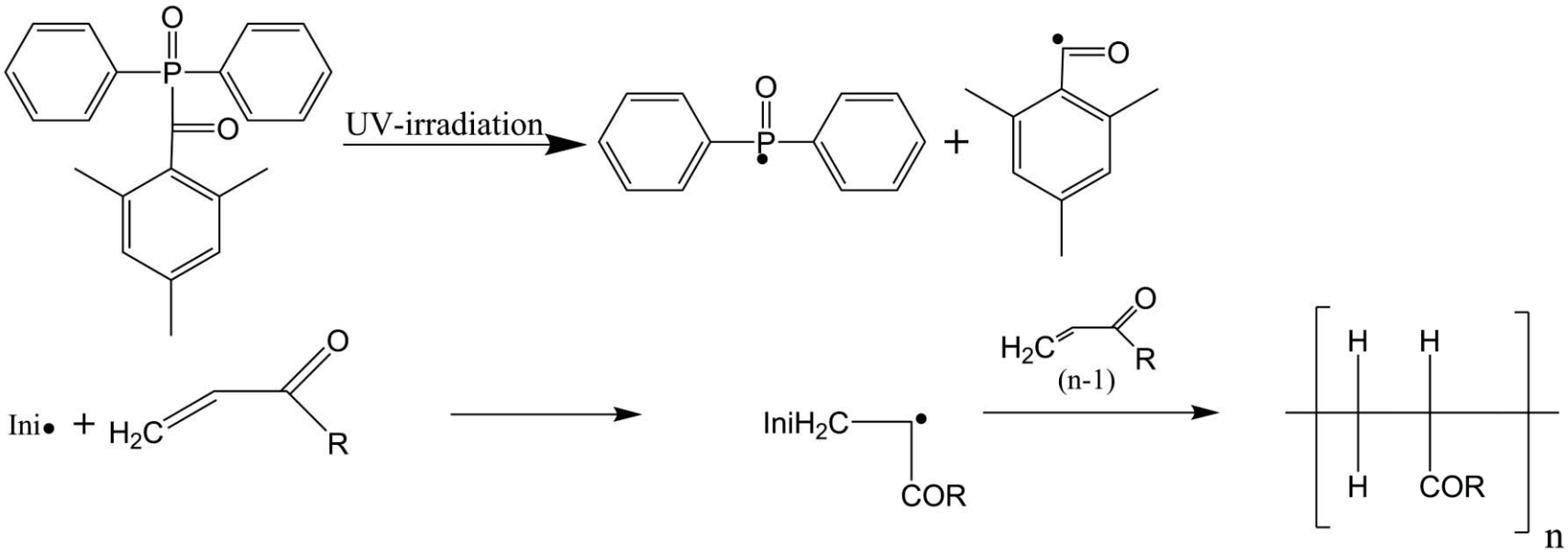
- UV initiator
  - Phosphine oxide



- Thermal initiator
  - Lauroyl peroxide



Radical polymerization



Mixture preparation

- Materials are mixed
  - up to 30.000 rpm
  - ambient conditions
- Ultrasonic bath

IKA T10 basic

[http://static.coleparmer.com]

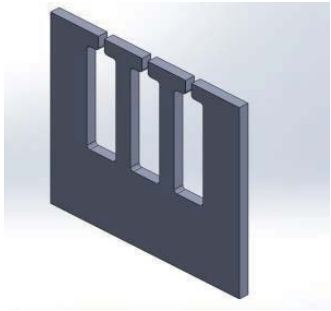
- Viscosity measurement
  - Cone and plate rheometer

Bohlin Rheometer CVO 50

[http://mb.uni-paderborn.de/]

Sample preparation

- For refractive index
  - Casting mold (silicon)
  - Glass plates
  - Fluorine ethylene propylene (FEP) foil
- Oxygen inhibition



casting mold

Sample preparation

- For refractive index
  - Casting mold (silicon)
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- Oxygen inhibition

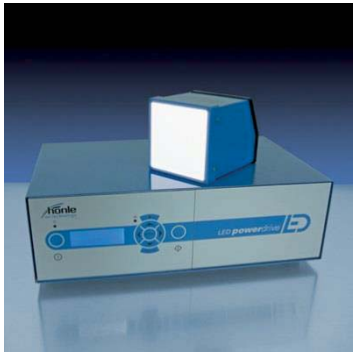
mold assembly

Sample preparation

- For refractive index
  - Casting mold (silicon)
  - Glass plates
  - Fluorine ethylene propylene (FEP) foil
- Oxygen inhibition

mold assembly

- Polymerization
  - Wavelength 405 nm



Hönle UV-Spot 100

[www.hoenle.de]

Sample preparation

- For refractive index
  - Casting mold (silicon)
  - Glass plates
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mold assembly

- Polymerization
  - Wavelength 405 nm

polymerized sample

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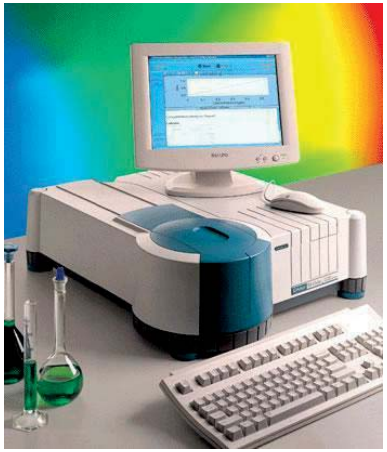
Sample characterization

- Refractive indices
  - Abbe-refractometer
  - Multi-wavelength
- Optical damping
  - UV-Vis spectroscopy
- Differential scanning calorimetry (DSC)
  - Glass transition temperature

ATAGO DR-M2/1550

[www.atagorus.ru]

refractometer surface

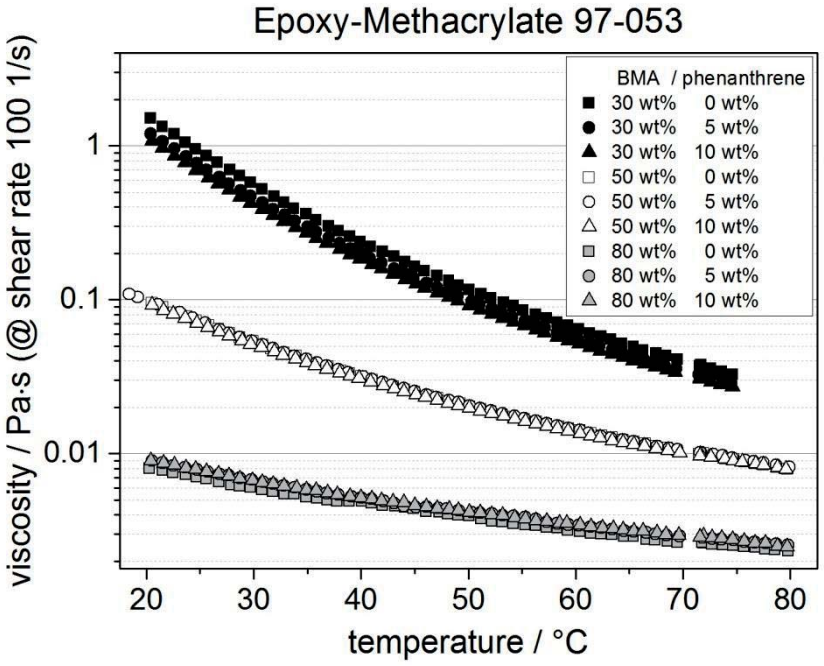


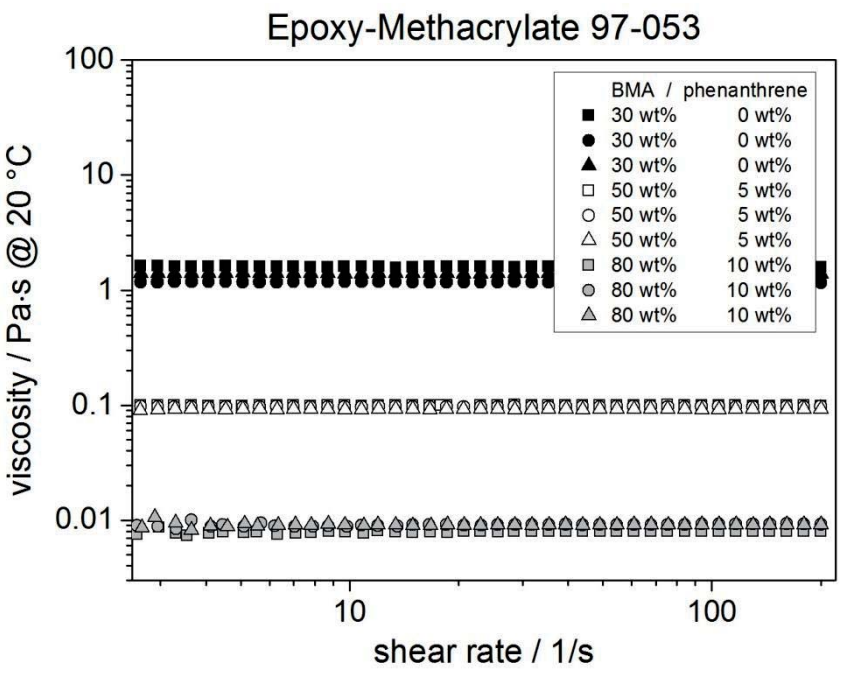
Varian Cary 50 UV-Vis

[www.speciation.net]

Viscosity of Epoxy Methacrylate 97-053 + BMA

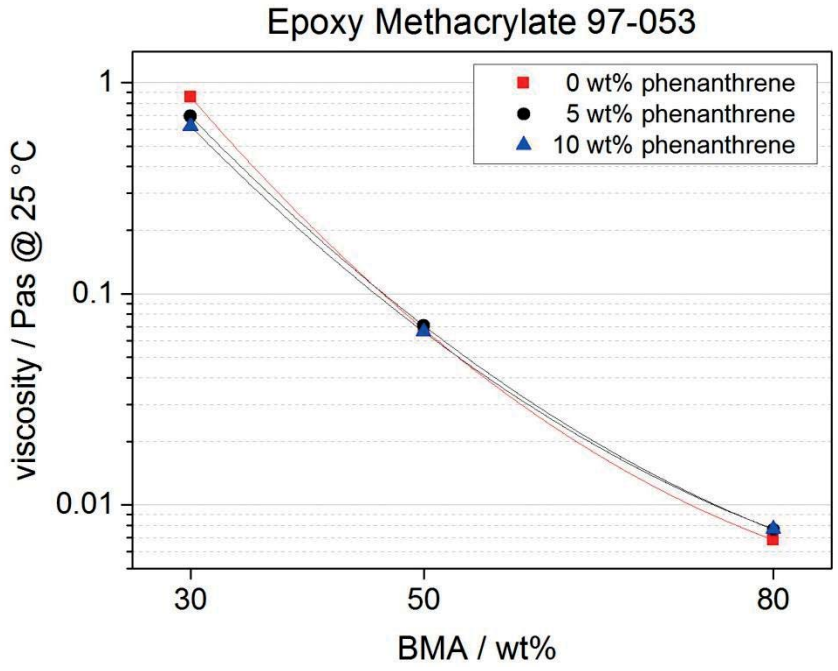
- Temperature dependency
- Newtonian behavior

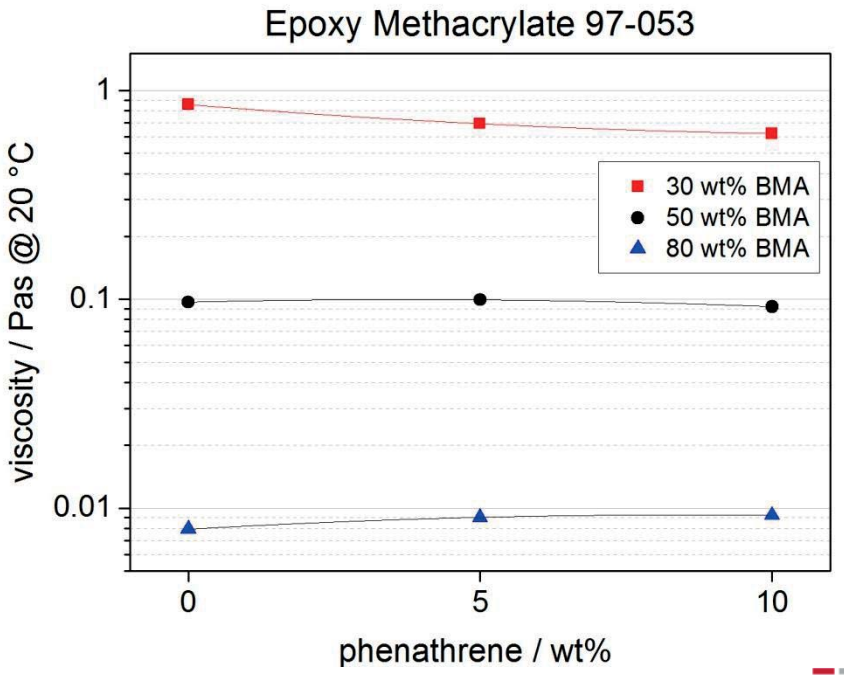




Viscosity of Epoxy Methacrylate 97-053 + BMA

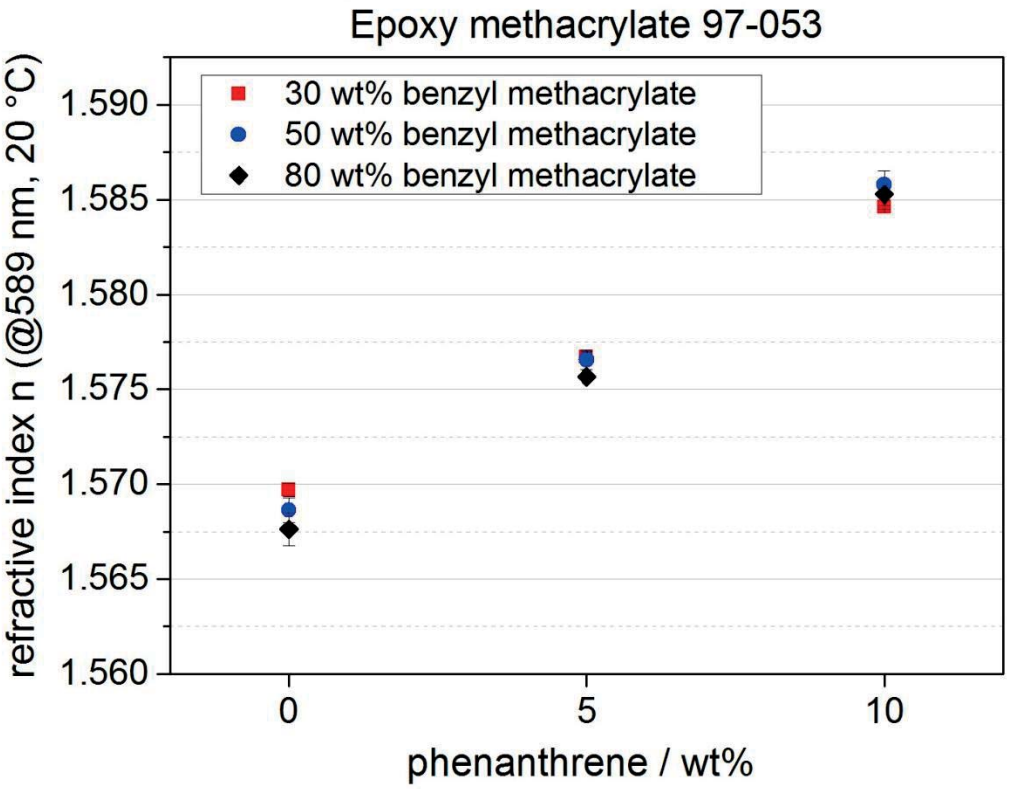
- Dependence on BMA
- Dependence on phenanthrene





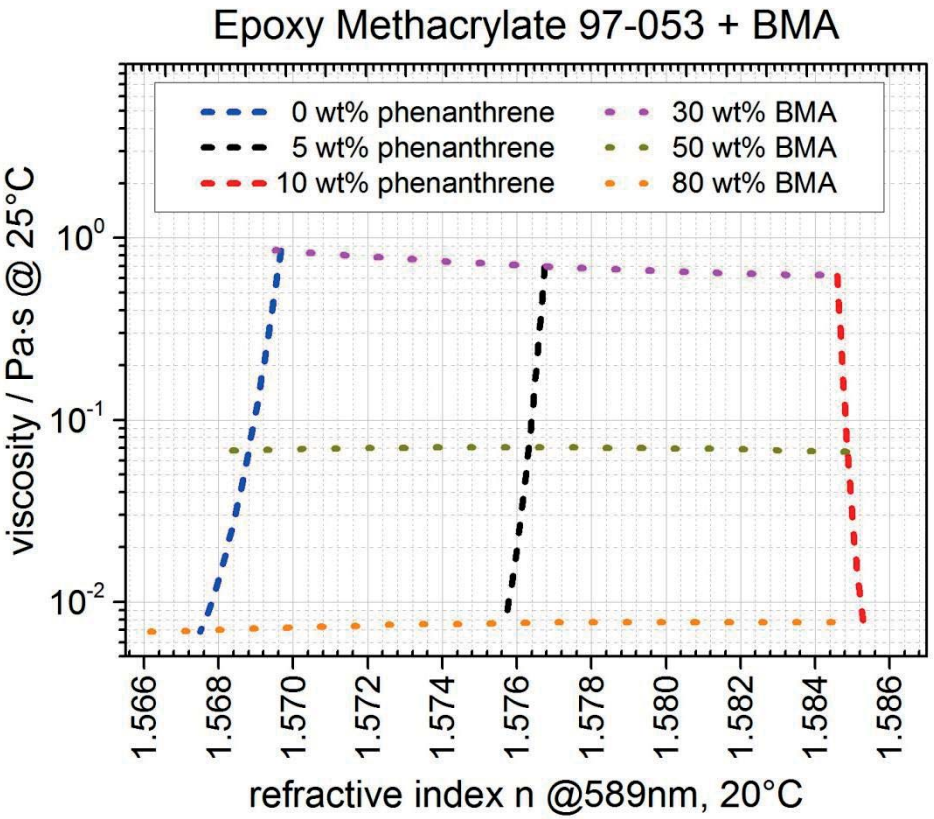
Refractive index

- Polymerized samples
- Phenanthrene increases refractive index
  - 0 wt%: 1.568 – 1.570
  - 5 wt%: 1.575 – 1.577
  - 10 wt%: 1.585 – 1.586
- BMA has low influence



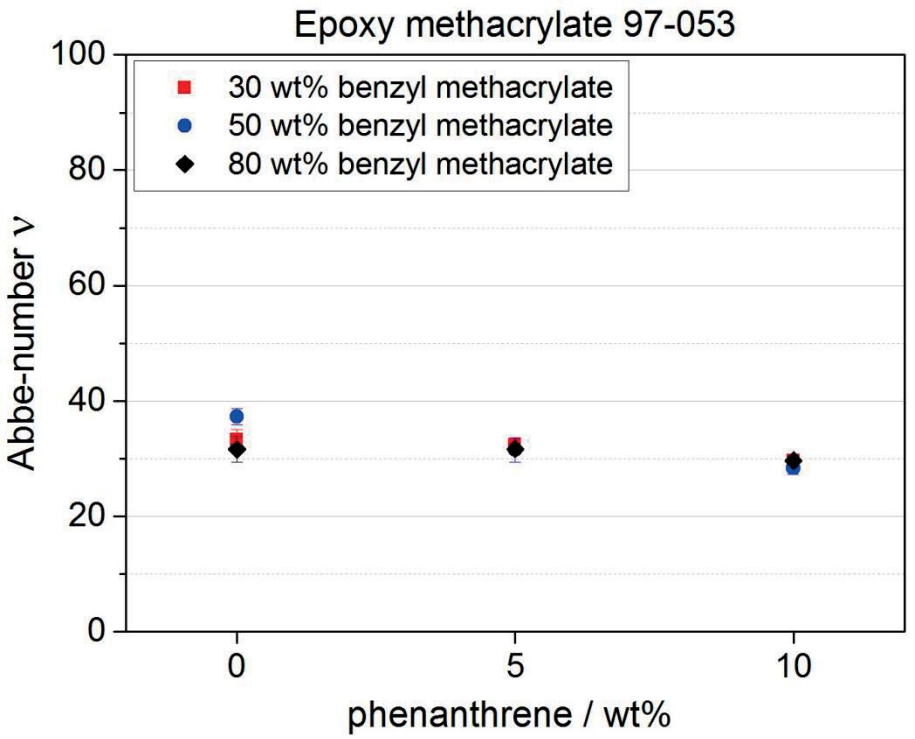
Data combined

- Viscosity
  - Refractive index
- Refractive index
  - Viscosity
- Easy lookup



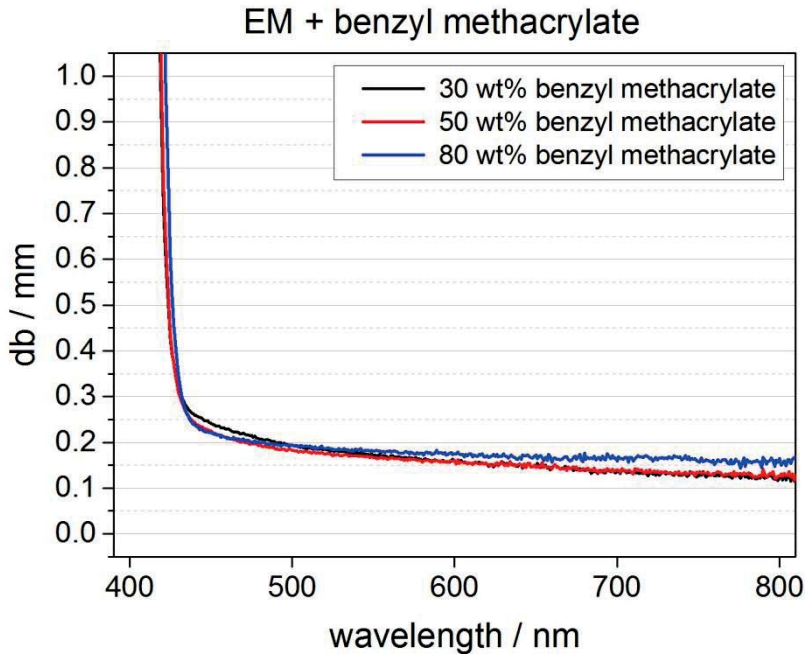
Abbe number

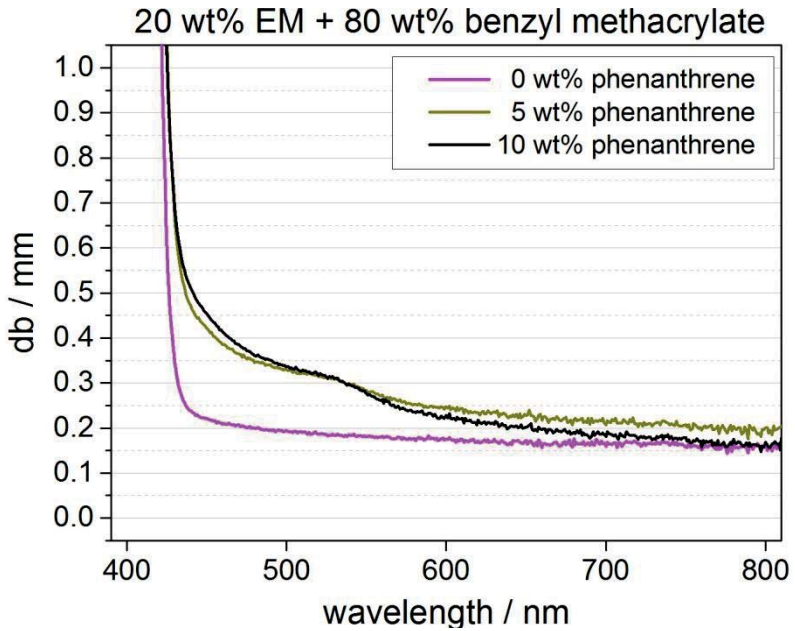
- Polymerized samples
- Phenanthrene decreases Abbe number
- BMA has low influence



Optical damping of Epoxy Methacrylate (EM) + BMA

- Independent on BMA
- Dependent on phenanthrene





Printed “waveguide”

- Ink-jet
  - width appr. 180 µm
  - height appr. 40 µm

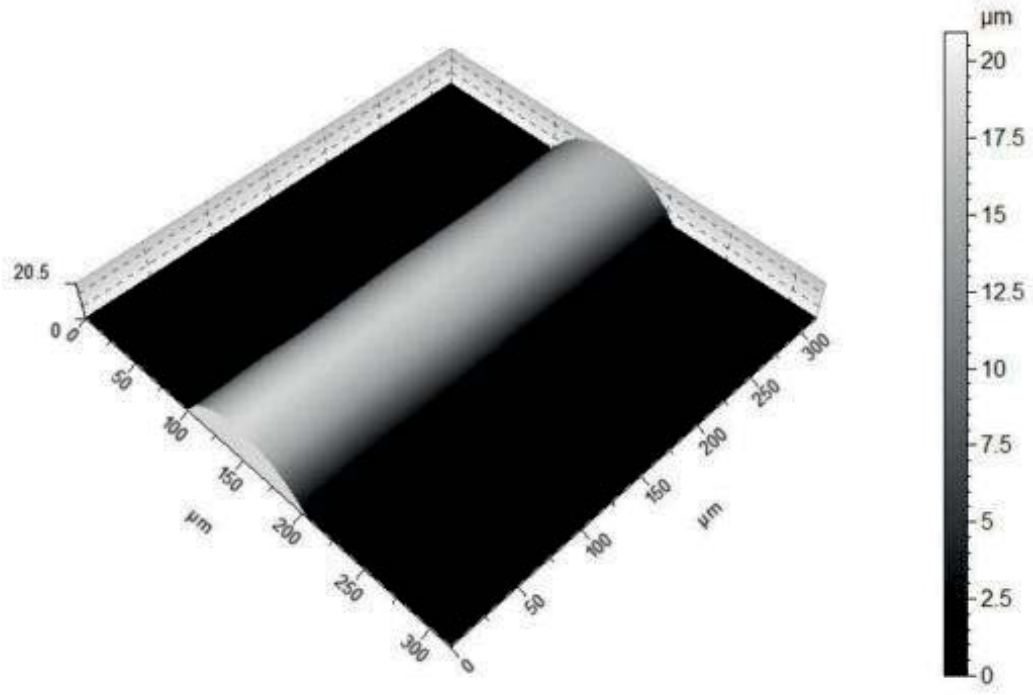


Image of inkjet-printed waveguide taken by confocal microscopy

[Wolfer et al., Procedia Technology, 2014]

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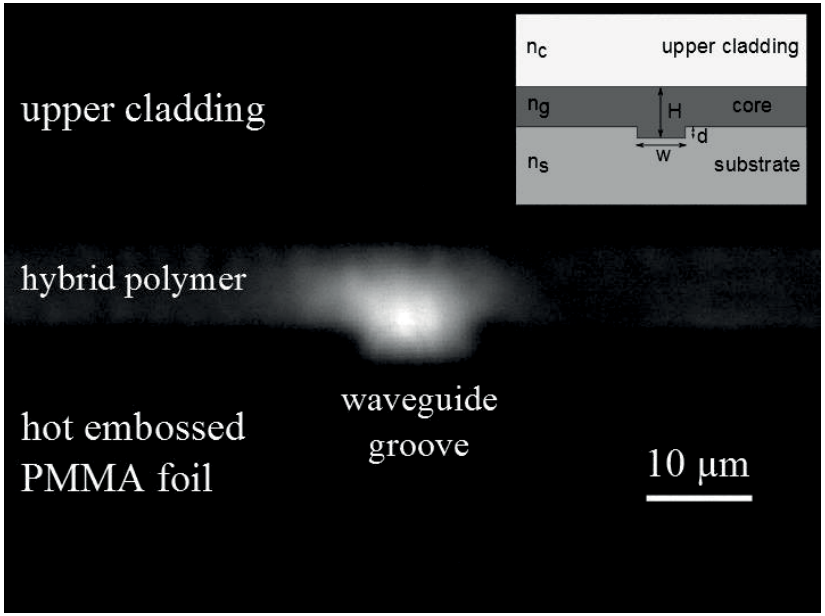
Spincoated waveguide

- width appr. 10 µm
- height appr. 5 µm
- monomode



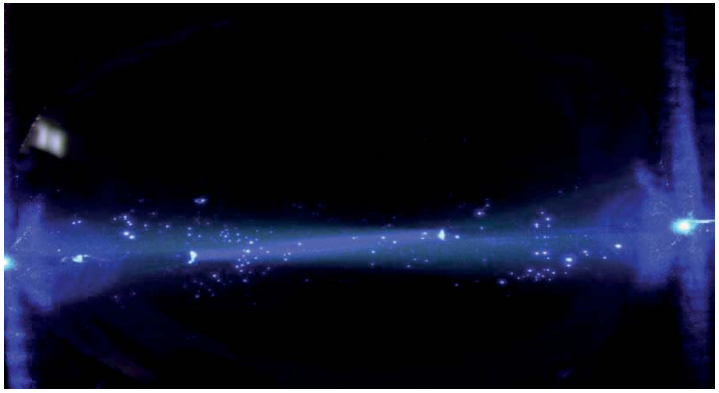
Output facet of a fabricated single-mode inverted rib wageguide

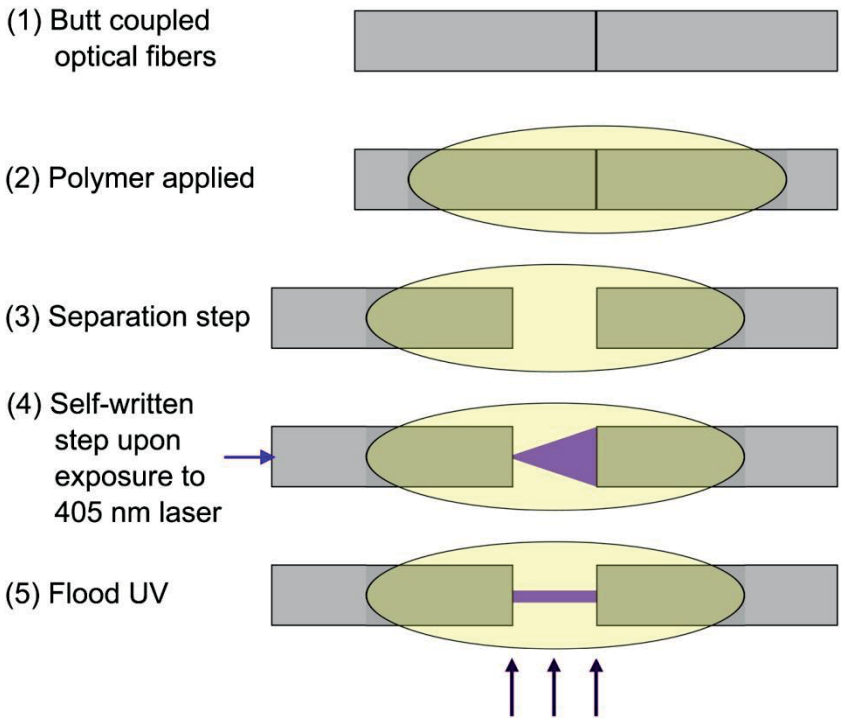
[Gleissner et al., Eurosensors Conference, 2015]

Planar Optronic Systems

Self writing waveguide

- Laser writing through monomer
- Between two fibers
- Low loss connection



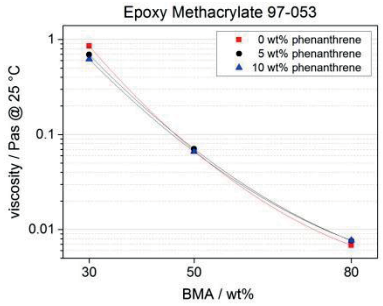


Schematic of the different process steps of the self-written waveguide formation

[Günther et al., Optics Letters, 2015]

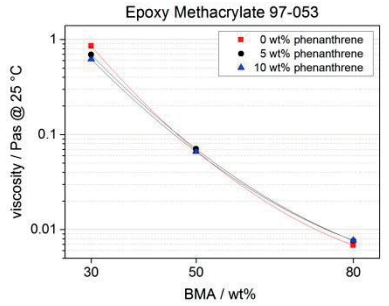
Summary

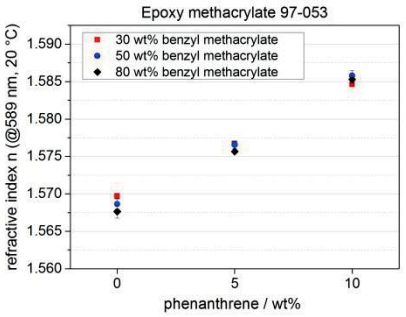
- Viscosity adjustable in a wide range
  - 1.5 Pa·s > η > 8 mPa·s (@ 20 °C)
  - Suitable for different shaping methods
  - Range can be extended



Summary

- Viscosity adjustable in a wide range
  - 1.5 Pa·s > η > 8 mPa·s (@ 20 °C)
  - Suitable for different shaping methods
  - Range can be extended
- Refractive index tunable
  - 1.570 < n < 1.585 (@ 20 °C, 589 nm)
  - Independent of viscosity





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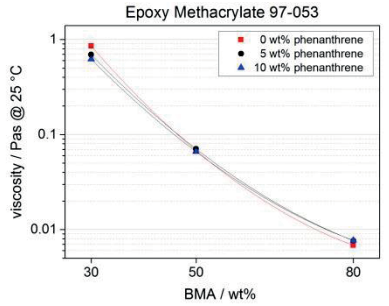
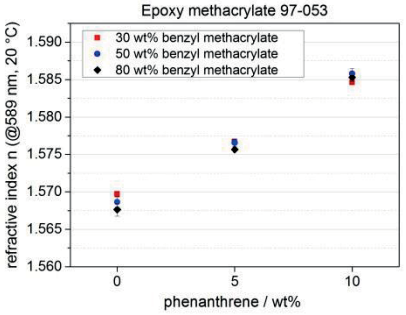
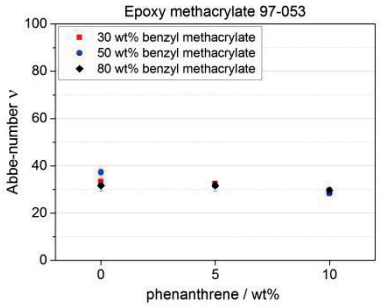
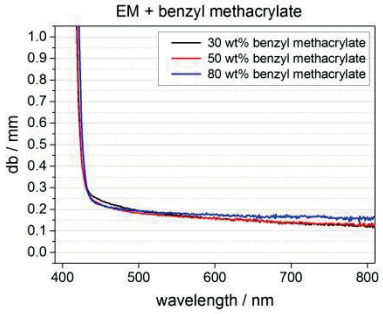
  - 1.570 < n < 1.585 (@ 20 °C, 589 nm)
  - Independent of viscosity
- Dispersion
  - Abbe numbers: 29 to 38
- Optical damping
  - As low as 0.15 dB/mm @600 nm









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