Tuning the Optical and Rheological Properties of Host-Guest Systems based on an Epoxy acrylate and MMA

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Collaborative Research Center

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

Polymer foil
[http://www.planos.uni-hannover.de]
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Why polymers?

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

Polymer foil
[http://www.planos.uni-hannover.de]
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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
    \[ \approx 70 \text{ mPa}\cdot\text{s (at 70 °C)} \]
  - Offset printing
    \[ \approx 200 \text{ mPa}\cdot\text{s (RT)} \]
  - Spin coating
    \[ \approx 100 \text{ mPa}\cdot\text{s} - 1000 \text{ mPa}\cdot\text{s (RT)} \]
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Adjustment of refractive indices

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

Computed 3D model of printed waveguide (Wolfer, University of Hannover 2013)

Friday, 11:00 Track 2
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Materials

- Prepolymer
  - Syntholux® (SYNTHOPOL), 80 % TPGDA

- Comonomer
  - EGDMA

- Dopant
  - Phenanthrene

- UV initiator
  - phosphine oxide

- Thermal initiator
  - lauroyl peroxide
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Radical polymerization

\[ \text{Initiation} + \text{H}_2\text{C} = \text{COR} \rightarrow \text{Initiation} + \text{COR} \]

\[ \text{Initiation} \rightarrow \text{Polymer} \]

UV-irradiation
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Mixture preparation

- Materials are dispersed
  - up to 30,000 rpm
  - ambient conditions
- Ultrasonic bath

- Viscosity measurement
  - Cone and plate rheometer

IKA T10 basic
[http://static.coleparmer.com]

Bohlin Rheometer CVO 50
[http://mb.uni-paderborn.de/]
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Sample preparation

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

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

- Polymerization
  - Wavelength 405 nm
  - 8 min, 25% power

Hönle UV-Spot 100
[www.hoenle.de]
Sample preparation

- For refractive index
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- Polymerization
  - Wavelength 405 nm
  - 8 min, 25 % power
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]

Varian Cary 50 UV-Vis
[www.speciation.net]
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Viscosity Syntholux + EGDMA

- Temperature dependency
- Newtonian behavior

![Graph showing viscosity vs. shear rate and temperature for Syntholux + ethylene glycol dimethacrylate (EGDMA)]

![Graph showing viscosity vs. shear rate at 20°C for Syntholux + ethylene glycol dimethacrylate (EGDMA)]
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Viscosity Syntholux + EGDMA

- Temperature dependency
- Newtonian behavior
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Viscosity Syntholux + EGDMA

- Temperature dependency
- Newtonian behavior
- Fitting curve for easy lookup
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Refractive index

- Liquid
- Polymerized
  - $1.55 > n > 1.515$
  - Shift increases

![Graph showing refractive index changes with EGDMA content.](image)
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Data combined

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

Graph showing the relationship between EGDMA content and viscosity, with refractive index as a parameter.
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Viscosity Syntholux + EGDMA + phenanthrene

- Temperature dependency
- Newtonian behavior
- Low influence of phenanthrene
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Refractive indices Syntholux + EGDMA + phenanthrene

- Phenanthrene increases refractive index
- Maximum phenanthrene content increases with EGDMA content
- Phenanthrene compensates EGDMA influence
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Printed “waveguides”

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

Ink-jet printed waveguides

[Bollgrün, University of Freiburg 2013]
Summary & Outlook

- Viscosity adjustable in a wide range
  - $48 \text{ Pa} \cdot \text{s} > \eta > 4 \text{ mPa} \cdot \text{s} (\text{at } 20 ^\circ \text{C})$
  - Suitable for different shaping methods
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Summary & Outlook

- Viscosity adjustable in a wide range
  - 48 Pa·s > η > 4 mPa·s (@ 20 °C)
  - Suitable for different shaping methods

- Refractive index tunable
  - 1.51 < n < 1.56 (@ 20 °C, 589 nm)
  - Phenanthrene can compensate influence of EGDMA
Summary & Outlook

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  - $48 \text{ Pa} \cdot \text{s} > \eta > 4 \text{ mPa} \cdot \text{s} \ (\text{@} \ 20 \ ^\circ \text{C})$
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- Refractive index tunable
  - $1.51 < n < 1.56 \ (\text{@} \ 20 \ ^\circ \text{C}, \ 589 \text{ nm})$
  - Phenanthrene can compensate influence of EGDMA

- Dispersion
  - Abbe number

- Optical damping

- Glass transition temperature
**Acknowledgements**

The **PlanOS** science team (alphabetical order):

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