Reversible birefringence in microstructures fabricated by two-photon polymerization

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• Motivation
• Resin preparation
• Azoaromatic compound and orientation
• Optimization of the resin
• Fabrication of microstructures via 2PA polymerization
• Birefringence in the microstructures
• Conclusions
Two-photon absorption polymerization have been used to fabricate 3D micromechanical actuators, photonic crystals, optical devices, etc.

Most of the structures reported until now are passive elements, whose properties cannot be changed by external means.

Here we demonstrate the fabrication by two-photon absorption polymerization of an optically active microstructure whose birefringence can be optically induced and erased.
Resin Composition

SR499

\[
\text{CH}_2\left\{\text{O-CH}_2\text{-CH}_2\right\}_2\text{O-CH}=\text{CH}_2
\]

ethoxylated(6) trimethyl-lolpropane triacrylate

reduces the shrinkage upon polymerization

SR368

\[
\text{O} \quad \text{N} \quad \text{O} \\
\text{N} \quad \text{N} \quad \text{O}
\]

tris(2-hydroxyethyl)isocyanurate triacrylate

gives hardness to the polymeric structure

Lucirin TPO-L

ethyl-2,4,6-Trimethylbenzoylphenylphosphinate

photoinitiator
Optically induced birefringence

To this resin we add the azodye Disperse Red 13 – DR13

Molecular orientation by excitation with linearly polarized light

Optically Induced birefringence
Optically induced birefringence mechanism

Before alignment

After alignment
Different compositions were studied

<table>
<thead>
<tr>
<th>SR368 % : SR499 %</th>
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<tbody>
<tr>
<td>0 : 100</td>
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<tr>
<td>30 : 70</td>
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<tr>
<td>50 : 50</td>
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<td>70 : 30</td>
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<td>100 : 0</td>
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To optimize the birefringence features of the composition we prepare films:

- L = 200 μm
- 1% DR13
Absorption spectrum of the resin with DR13

Sample 70:30 % (SR368: SR499)
Optimization of the resin

Experimental setup for birefringence measurement in films

- **HeNe** \((\lambda=632.8\ \text{nm})\)
- **Ar\(^+\)** \((\lambda=514.5\ \text{nm})\)

![Experimental setup diagram](attachment:experimental_setup.png)
Optimization of the resin

Sample 70:30 % (SR368: SR499)

Maximum birefringence $\Delta n = 10^{-4}$

Residual birefringence $\Delta n = 3 \times 10^{-4}$

$I = 600 \text{ mW/cm}^2$
Optimization of the resin

Residual rate for different compositions

SR368 : SR499
70 : 30 %

1 - more stable birefringence
2 - enough amount of SR499 to reduce microstructure shrinkage
Two-photon polymerization setup

Ti:sapphire laser oscillator
- 130 fs
- 800 nm
- 76 MHz
- 20 mW

Objective
- 40 x
- 0.65 NA
Scanning electron micrograph of a solid square structures containing DR13 fabricated by 2PA polymerization.

- good structural integrity and definition
Inducing birefringence in the microstructures

We induce optical birefringence in the fabricated microstructures

**Ar+ ion laser irradiation**

- 514.5 nm
- one minute
- intensity of 600 mW/cm²
Birefringence in the microstructure

The sample was placed under an optical microscope between crossed polarizers and its angle was varied with respect to the polarizer angle.

The structure is visible when the angle between the birefringence axis and the polarizer is an odd multiple of 45°.

This birefringence can be completely erased by irradiating the sample with circularly polarized light for three minutes.
Birefringence in the microstructure

Transmitted light through the analyzer as a function of \( \theta \), for the previous microstructure

Sinusoidal behavior typical of the birefringence

\[ T = \sin^2 \left( \frac{k\Delta nL}{2} \right) \sin^2 (2\theta) \]

\( \Delta n = 5 \times 10^{-5} \)
In summary we use 2PA to fabricate structures doped with an azoaromatic compound in which birefringence can be optically induced and erased. Such results open a new opportunities for the development of optical storage devices and photonic applications such as optical switches and connectors.
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